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OAK RIDGE
K-25 SITE

MARTIN MARIETTA

Data Evaluation Technical Memorandum on K-1070-A Contaminated Burial Ground, Oak Ridge K-25 Site, Oak Ridge, Tennessee

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Environmental Restoration Division
K-25 Environmental Restoration Program

Data Evaluation Technical Memorandum on K-1070-A Contaminated Burial Ground, Oak Ridge K-25 Site, Oak Ridge, Tennessee

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Oak Ridge K-25 Site
Oak Ridge, Tennessee 37831-7101
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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EXECUTIVE SUMMARY

The K-1070-A Contaminated Burial Ground was used for the disposal of unclassified low-level radioactive solid and mixed chemical waste. The majority of the waste was leached alumina that contained small quantities of uranium. This material was collected from the waste stream generated during uranium decontamination of process equipment. Small amounts of other uranium and thorium compounds, beryllium chips, boron, radioactive contaminated NaF, and unknown compounds were also buried at the site.

This Data Evaluation Technical Memorandum (DETM) is specific to the K-1070-A Contaminated Burial Ground and includes the findings of a multidisciplinary team that evaluated analytical data from soil samples. The DETM will serve to appraise the ability of the Phase 1 data to substantiate recommendations for further sampling and/or analyses that may be required to complete the site investigation for remedial investigation/feasibility study and environmental assessment. Additionally, the data are evaluated in relation to their validity and representativeness with respect to human-health risk assessment.

The soil investigation at the K-1070-A Contaminated Burial Ground found the area included in the soil survey relatively free of materials from the disposal area. Consequently, soil does not pose an imminent threat to human health or the environment. Additionally, the physical characterization of the site suggests that the greatest potential for the migration of contaminants from the site is via groundwater. It is recommended that at this time no further soil characterization be performed at the K-1070-A Contaminated Burial Ground, pending the results of the groundwater investigation. On completion of the groundwater investigation, the Phase 1 soil investigation results will be integrated with findings of the Waste Area Grouping 10 investigation to determine if additional soil sampling is necessary.

1. INTRODUCTION

The Oak Ridge K-25 Site, previously known as the Oak Ridge Gaseous Diffusion Plant (ORGDP), was built on the Oak Ridge Reservation (ORR) as part of the Manhattan Project during World War II to supply uranium-enriched material for nuclear weapons. Construction started in 1943, and the K-25 Building, the first diffusion facility for the large-scale separation of ^{235}U, was in full operation by August 1945. Additional buildings involved in the enrichment process, K-27, K-29, K-31, and K-33, were operational by 1956. In response to the nation's post-war nuclear emphasis, plant operations were modified to include the production of uranium compatible with reactors used to generate electric power. The K-25 Site continued to provide enriched uranium until 1987.

As a result of the byproducts generated during plant operations, hazardous waste treatment, storage, and disposal (TSD) facilities were created at the K-25 Site. Some of these facilities continue to receive hazardous wastes, and others have been decommissioned. The enactment of the Resource Conservation and Recovery Act (RCRA) in 1976 created a management system for hazardous wastes that mandates permitting of currently operating TSD facilities.[1] Furthermore, the enactment of the Hazardous and Solid Waste Amendments (HSWA) to RCRA in 1984 extended the authority of the Environmental Protection Agency's (EPA) to correct releases to all media from all solid waste management units (SWMUs) at RCRA facilities.[2] A SWMU is defined as any "discernible waste management unit at a RCRA facility from which hazardous waste or hazardous constituents might migrate, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at a facility at which hazardous wastes or hazardous constituents have been routinely and systematically released."[3] To help ensure compliance with these acts, a Remedial Action Program (RAP) has been established under the auspices of the K-25 Site Environmental Restoration Program and is responsible not only for detection and correction of releases from regulated units, but also for clean-up of continuing releases from other waste management units and practices at the K-25 Site.

All activities under the K-25 Site RAP are conducted using the RCRA Facility Investigation (RFI) approach as described by the EPA.[3] This approach calls for the preparation of site-specific RFI plans for individual SWMUs or groupings of SWMUs. These plans identify actions necessary to characterize the hydrogeology of the site and the nature and extent of releases or the potential for release of hazardous materials from SWMUs into soil, groundwater, surface water, vegetation, and/or air.

ORR was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List in the November 1989 *Federal Register* (54 *FR* 48184). Therefore, most of the K-25 Site SWMUs will also fall under the jurisdiction of the mandates of CERCLA as operable units.

General information in support of the preparation of RFI plans for those SWMUs located within the jurisdiction of the K-25 Site is found in *RCRA Facility Investigation Plan General Document, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee* (K/HS-132, Revision 1, May 1989; hereafter referred to as the General Document).[4] The General Document serves as a comprehensive reference for individual RFI plans as well as for other

K-25 Site RFI documentation. The General Document characterizes the K-25 Site environment, locates the SWMUs in the K-25 Site geographical setting, and provides a perspective on the scope of operation. Sampling strategies, quality assurance (QA), and quality control (QC) associated with sampling, analysis, and data management are discussed, along with procedures established to protect the health and safety of employees and the public.

Existing documentation specific to the ongoing investigation of the K-1070-A Contaminated Burial Ground includes the *RCRA Facility Investigation Plan: K-1070-A Contaminated Burial Ground* (K/HS-133; hereafter referred to as the site-specific RFI Plan),[5] *Field Observation Report for K-1070-A Contaminated Burial Ground RCRA Facility Investigation* (K/ER-7),[6] *Work Plan: Quality Assurance/Quality Control Health and Safety Plan for the Site Characterization of K-1070-A* (K/ER-5),[7] and *Applicable or Relevant and Appropriate Requirements for K-1070-A* (K/ER-28).[8] The soil data considered in the present document is included in the *Site Characterization Summary: K-1070-A Contaminated Burial Ground* (K/ER-3/D1).[9]

Groundwater movement and its relation to contaminant transport at the K-25 Site necessitates that groundwater be treated as a separate operable unit for each waste area grouping (WAG). Each WAG consists of SWMUs which have been grouped according to groundwater divides. The strategy used to delineate the WAGs is included in the *K-25 Site Groundwater WAG Strategy Document*, K/ER-22.[10] The K-1070-C Contaminated Burial Ground is contained in WAG 10. Therefore, the scope of this report is restricted to site soil contamination. Groundwater in the vicinity of K-1070-A will be addressed in the WAG 10 groundwater investigation. An integrated evaluation of the soil and groundwater investigations will be incorporated in future decisions addressing remedial alternatives.

This Data Evaluation Technical Memorandum (DETM) focuses on the ability of the soil investigation to determine whether contamination from the site has migrated to the soil zone surrounding the burial ground. Contained within this document are historical and operational information, background information related to the physical characteristics of the area, a statistical review of the Phase 1 data, and a preliminary screening of the data to identify potential contaminants of concern. This DETM is specific to the K-1070-A Contaminated Burial Ground and includes the findings of a multidisciplinary team that evaluated analytical data from soil samples. The DETM will serve to provide an appraisal of the Phase 1 data in terms of their ability to substantiate recommendations for further sampling and/or analyses that are required to complete the site investigation for remedial investigation/feasibility study and environmental assessment. Additionally, the data are evaluated in relation to their validity and representativeness with respect to human-health risk assessment.

2. DESCRIPTION OF THE STUDY AREA

2.1 PHYSICAL CHARACTERISTICS

2.1.1 Geographic Location

The K-25 Site complex is located near Oak Ridge, Tennessee, ~20 mi northwest of Knoxville, Tennessee (Fig. 1), and 6 mi east of the city of Oak Ridge (Fig. 2). The K-1070-A Contaminated Burial Ground is a 3-acre tract of land located outside the security perimeter fence on the southeast slope of Blackoak Ridge, north of the K-25 Site main plant area, and northwest of Building K-33. K-1070-A lies ~600 ft northwest of West Perimeter Road, and vehicular access is controlled by a locked gate. No waste management sites are located upgradient of K-1070-A. The K-1070-A Contaminated Burial Ground is site 36 on Fig. 3, a site location map of the area.

2.1.2 Climatology

Weather patterns in Oak Ridge are generally temperate, with warm, humid summers and cool winters. Extreme temperatures are uncommon because of the moderating influences of the adjacent mountain ranges. Annual average precipitation is 1.36 m, including ~0.25 m of snowfall.[11] The greatest precipitation occurs in January, February, and July; spring and autumn months are relatively dry.

Wind conditions in the Oak Ridge area are some of the calmest in the United States. The major contributor to this stability of air movement is the Cumberland Plateau. In addition, the area is protected by the Appalachian Mountains from the hot, southeasterly winds and tropical storms which sometimes develop along the Atlantic coast. Poor air dilution typically occurs in October due to slow-moving high-pressure cells. Severe electrical storms, wind storms, and tornadoes rarely occur in the Oak Ridge area. However, an investigation of the wind patterns in the ORR area confirmed good ventilation up and down the valleys. This ventilation helps circulate the air masses over Oak Ridge. Prevailing winds blow up-valley from the southwest during the day and down-valley from the northeast in the early evening and at night. This effect, which is due to the channeling of wind by the regional ridge and valley topography, is not as evident in the vicinity of the K-25 Site, which is in a relatively open area.[12]

2.1.3 General Regional Demography

The K-25 Site is part of the 63,000-acre federally-owned ORR, which is located in Anderson and Roane counties. There are five counties surrounding the reservation: Anderson, Knox, Loudon, Morgan, and Roane. The combined population of these five counties is slightly greater than 500,000.

The two major population centers within 50 mi of the site are Oak Ridge (population ~28,000), which lies 6 mi east of the plant, and Knoxville (population ~183,000), which is

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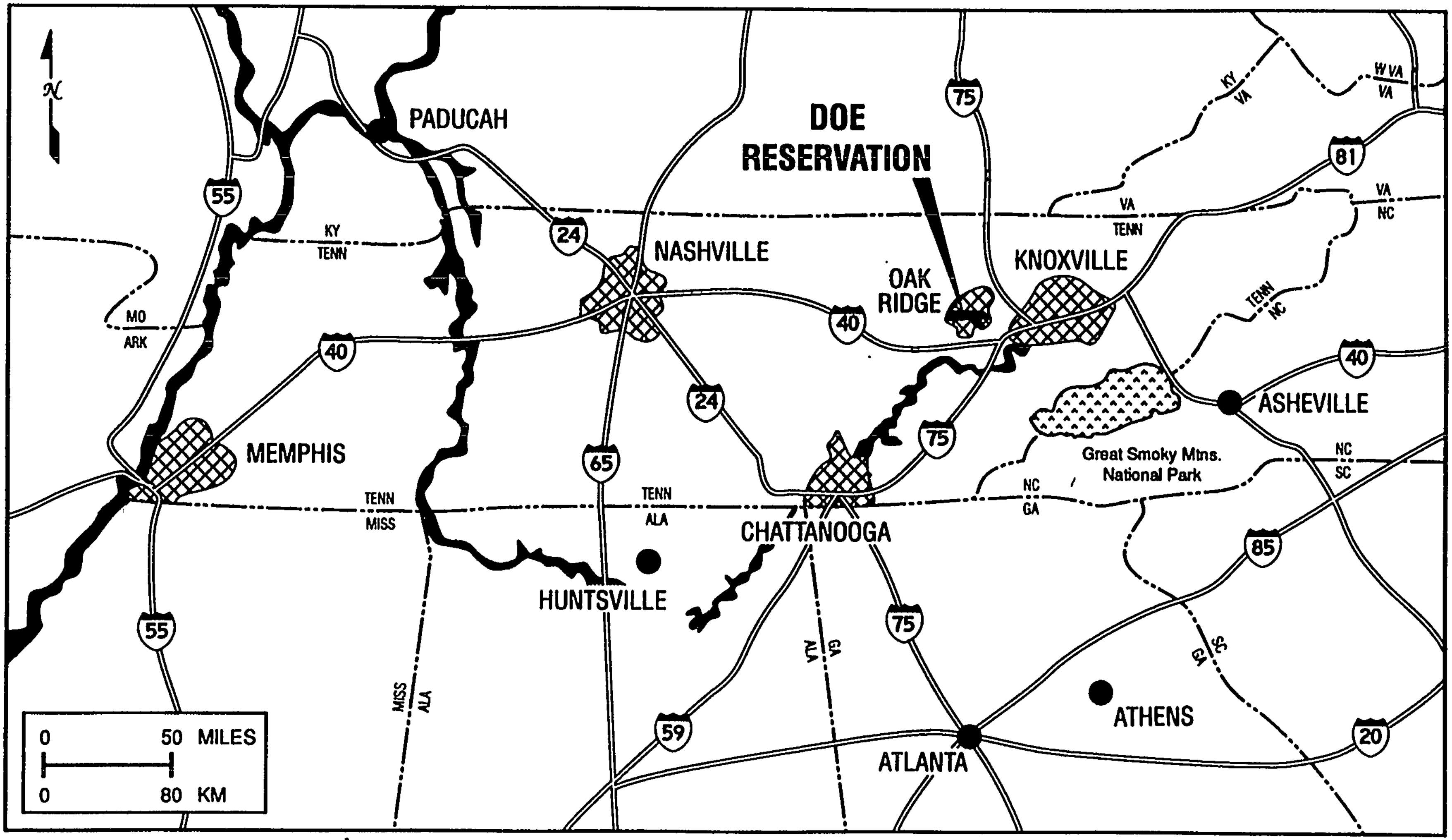

Fig. 1. Regional location of the K-25 Site.

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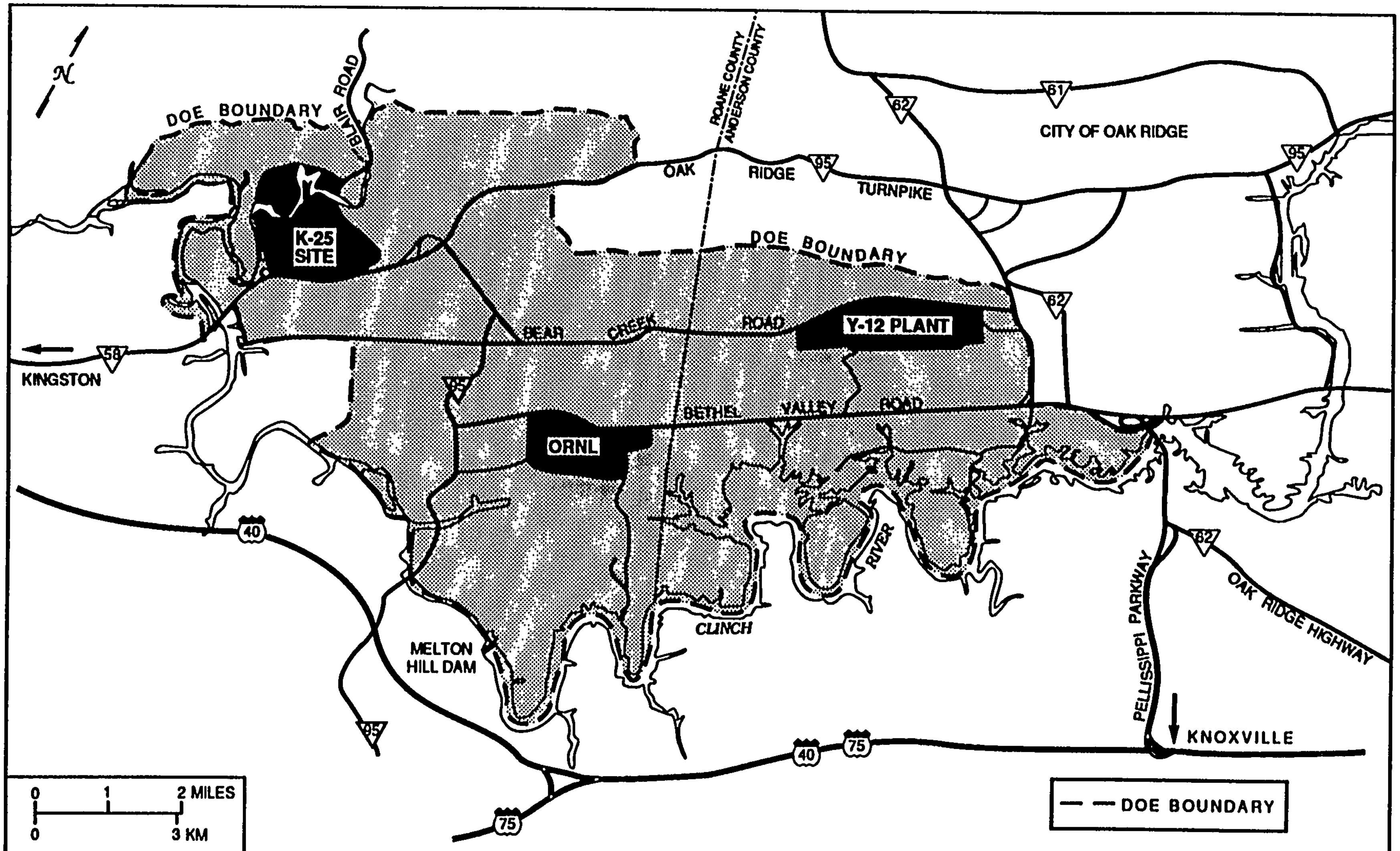

Fig. 2. Location of the K-25 Site with respect to the city of Oak Ridge.

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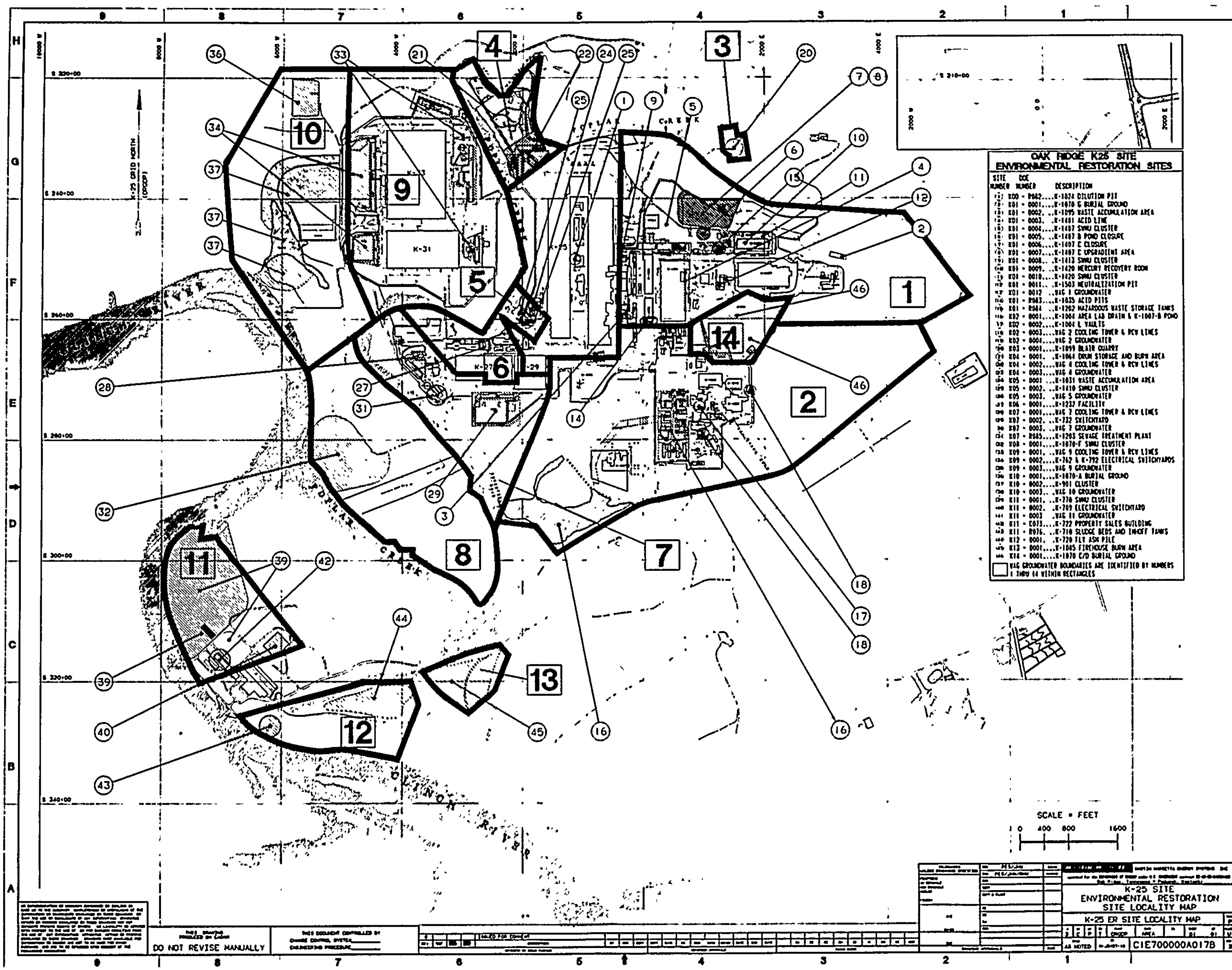

Fig. 3. Site location map of K-25 Site.

~20 mi east of the site. Several smaller cities are located within the nearby counties: Clinton (population ~5200), Harriman (population ~8300), Kingston (population ~4500), Lenoir City (population ~5500), Loudon (population ~4000), Oliver Springs (population ~3600), and Rockwood (population ~5800) (Environment, Safety, and Health, 1986).[13] The locations of these cities are shown in Fig. 4.

The largest population (~3300) within a 2-mi radius of the K-25 Site is composed of the on-site employees of the facility. In addition, a small number of visitors are present at the site at any given time. Other nearby facilities (Fig. 4) where local residents may be employed include the two industrial sites in the Clinch River Industrial Park and the Security Guard Training Facility on Bear Creek Valley Road. One of the industrial facilities is operated by the International Technology (IT) Corporation and employs 70 workers; the other is operated by the Scientific Ecology Group (SEG) and employs 150 workers. The population present at the Security Guards Training Facility is dependent upon the on-going activities.

The nearest privately owned residential properties are in the Sugar Grove Valley, Dyllis, and Poplar Springs communities. In these communities there are 48 homes altogether. Forty-two of these are located ~1.5 mi north of the K-25 Site in the Sugar Grove Valley and Dyllis communities. The remaining six homes are located 2 mi west-southwest of the plant area and west of the Clinch River, as part of the Poplar Springs community. Assuming an average of four occupants per dwelling, the residential population represented within a 2-mi radius is less than 200. Other residential areas near the K-25 Site are Bradbury, which is located across the Clinch River, ~5 mi to the south, and Edgewood and Lawnville, which are located immediately west-northwest of the Poplar Springs community.

2.1.4 Land Use

The region around the K-25 Site complex contains areas of agricultural, residential, industrial, and recreational uses.[4] Because the land immediately surrounding the plant is a federal reservation, it is primarily undeveloped.

Agricultural uses of nearby land include: limited-scale private gardening; raising of tobacco, corn, wheat, and soybeans as cash crops; raising of beef cattle; and dairy farming. Some areas are also used for commercial logging.

Nearby industrial use of the land includes the Oak Ridge National Laboratory, the Oak Ridge Y-12 Plant, Phyton Technologies, Inc., SEG, and the IT Corporation Bear Creek Radiological Laboratory. Only the SEG and IT Corporation laboratories are within 2 mi of the K-25 Site. Tennessee Valley Authority facilities near the plant are the Melton Hill Dam, the Bull Run Steam Plant, and the Kingston Steam Plant. None of these is within 6 mi of the plant.

The nearby Watts Bar Lake Embayment/Clinch River waterway is used as a recreational area by both pleasure boaters and fishermen. There are a number of small camping areas and boat launching ramps in the vicinity; one of the ramps is located slightly more than a mile upstream of the K-25 Site. There are no other recreational facilities within 2 mi of the K-25 Site. A small dirt surface racetrack is located ~4 mi south of the plant and attracts several thousand spectators during the racing season. There is a public swimming area at Melton Hill

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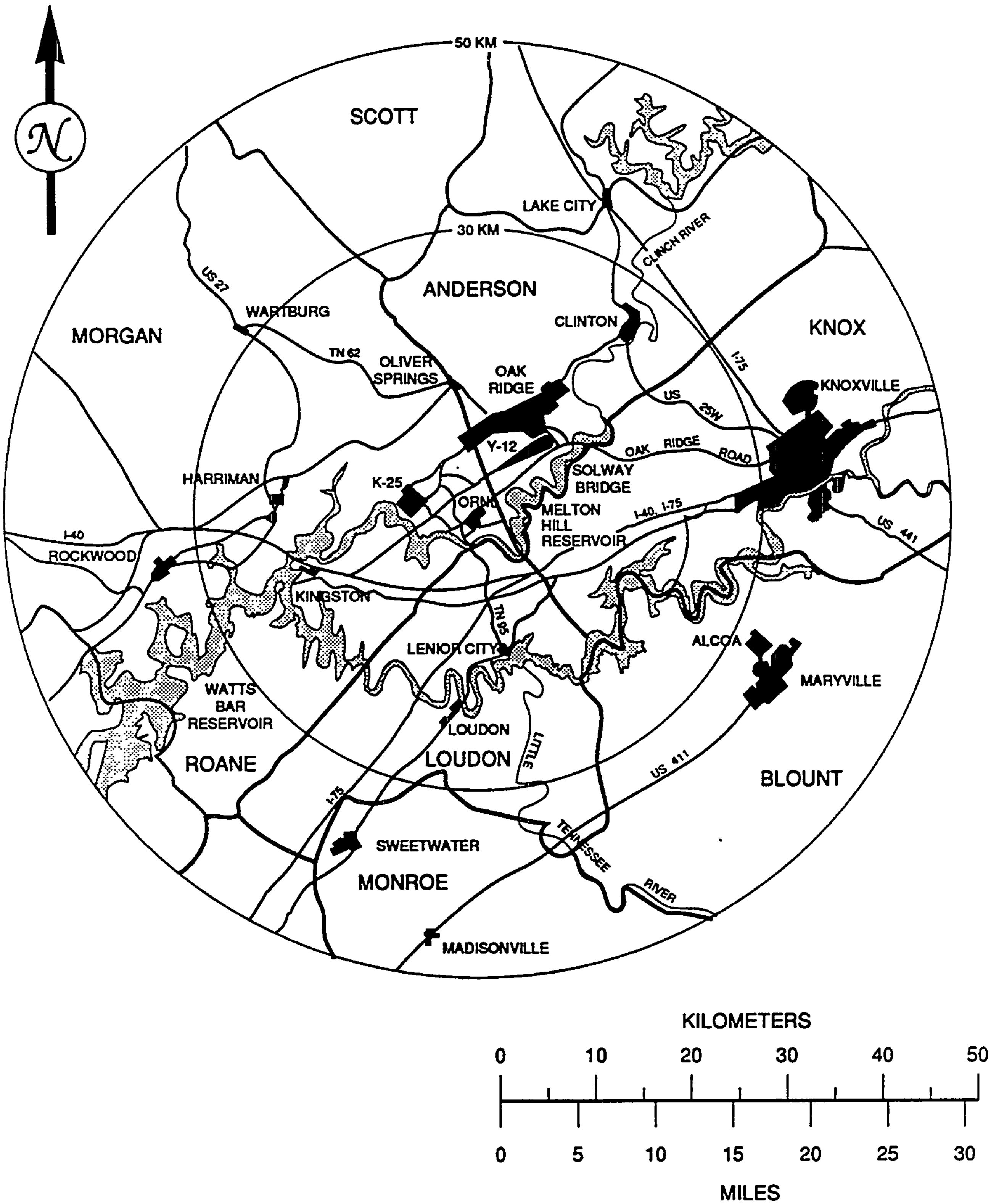


Fig. 4. Communities within a 30-mi radius of the K-25 Site.

Dam, 7 mi southeast and upstream of the plant. Sport hunting of game birds and game animals occurs seasonally in the region surrounding the plant. Also, deer hunting is authorized on some parts of the ORR as a population control measure; some of these seasonal hunting areas are within 2 mi of the K-25 Site. All harvested animals are screened for beta and gamma radiation contamination, and animals with high radiation readings are confiscated.

2.2 GEOLOGY AND HYDROLOGY

The general geology of the K-25 Site area has been described in *Hydrogeology of the Oak Ridge Gaseous Diffusion Plant*.[14] Two additional sources that have been utilized to interpret the geology of the K-25 Site area are the "ORGDP Geologic Map" by R. H. Ketelle,[15] and the "Geological Map of the Oak Ridge Area, Tennessee."[16] The following geologic descriptions and discussions of hydrogeology are based on these sources, the lithologic logs of the 9 monitoring wells, and 23 soil boring logs contained in the *RCRA Facility Investigation K-1070-A Contaminated Burial Ground Field Observation Report*.[6] Site-specific data (e.g., permeabilities) are referenced as applicable.

2.2.1 Geology

2.2.1.1 Regional setting

The K-25 Site area is underlain by sedimentary rocks of the Paleozoic age consisting mainly of interbedded units of limestone, dolomite, shale, and sandstone. In many instances, compositions are gradational or intermediate, e.g., dolomitic limestone, calcareous shale, etc. The general geology of the K-25 Site is shown in Fig. 5.

The dominant structural features in East Tennessee are the numerous northeast-southwest trending thrust faults, such as the Whiteoak Mountain fault, which traverses the southeast side of the K-25 Site area (Fig. 5). Most structural trends and deformational anomalies in the area are related to the thrust faults. Soils in the K-25 Site area uplands are mainly residual in origin. Colluvial soils occur along the bases and lower slopes of the ridges, and alluvial materials have been deposited in the floodplains and channels of the streams. Silty residual clays up to 30 ft or more in thickness occur over the carbonate formations (dolomite and limestone), while much thinner, silty-to-sandy, or "chippy," soils are found over the sandstones and shales.

2.2.1.2 Topography

The K-1070-A Contaminated Burial Ground is situated at the flank of the southeast slope of Blackoak Ridge, a prominent, broad, and irregular ridge which rises to the northwest as much as 280 ft above the site. The surface of the burial ground slopes uniformly to the south and southeast; the average slope across the site is ~9%. The topography of the immediate vicinity of K-1070-A is shown in Fig. 6.

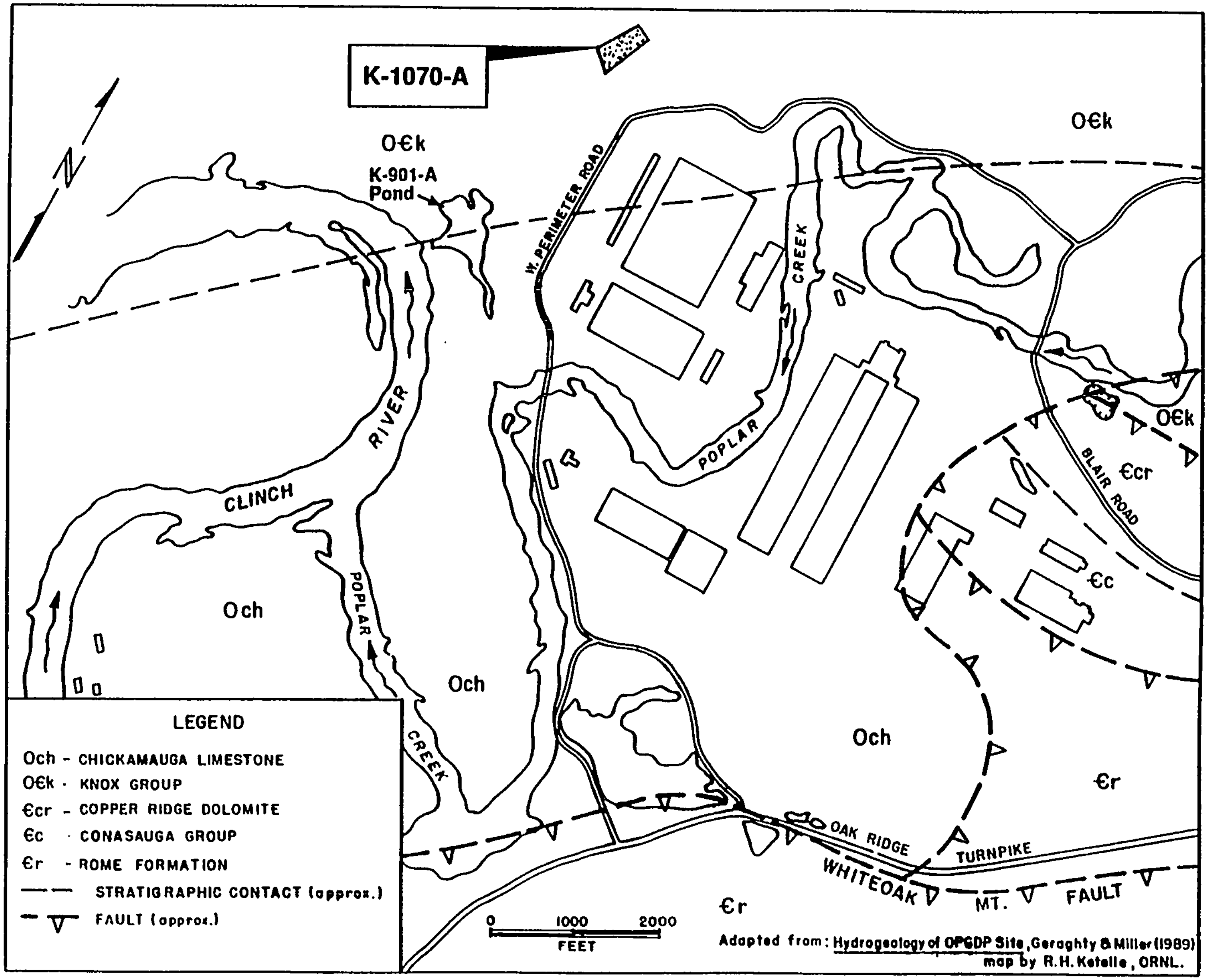


Fig. 5. General geology of the K-25 Site.

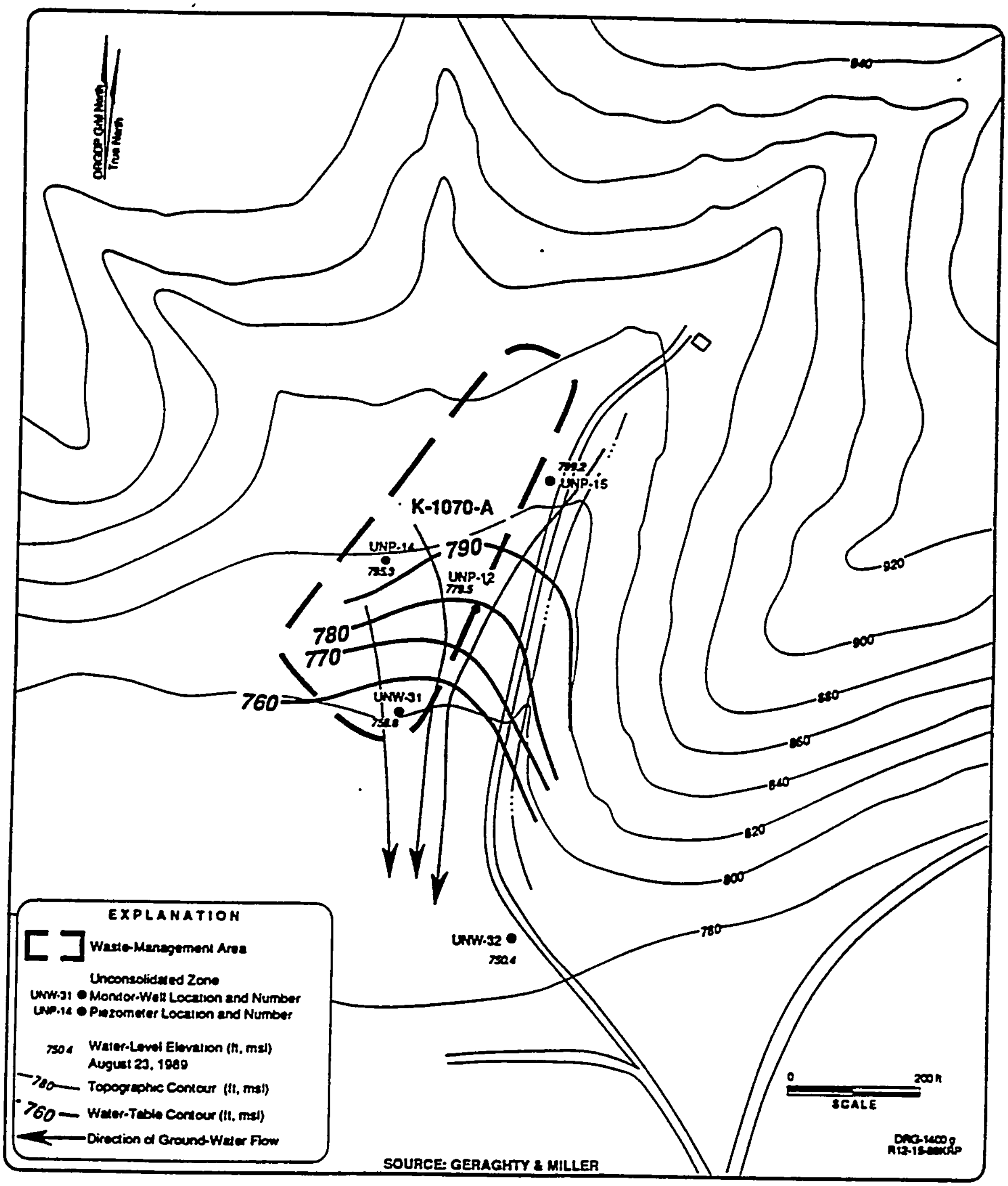


Fig. 6. Topography in the vicinity of K-1070-A.

2.2.1.3 Stratigraphy

Bedrock beneath the K-1070-A site is composed of strata of the middle part of the Knox Group (Fig. 5). The Knox Group is generally composed of gray, fine-to-medium grained siliceous dolomite and dolomitic limestone with some interbedded limestone, particularly in the upper part of the group. The Knox here is mostly medium- to thickly-bedded, although some thinly-bedded zones may be present. The Knox Group, which underlies Blackoak Ridge, is relatively resistant to erosion.

There are no bedrock outcrops in the immediate vicinity, but the Knox Group beneath K-1070-A is described in the well logs and in the *Field Observation Report* as light gray to blue-gray with considerable "porcelaneous" chert.[6] The chert generally occurs as a zone of nodules or lenses or in thin, irregular beds. The logs of the soil borings (Appendix A) indicate that the rock is both fractured and cavernous. The Knox dolomite here has weathered extensively to form a thick mantle of reddish-brown to yellowish-red, silty, residual clay with varying amounts of chert (silica) fragments. The logs also show the clay to be generally very plastic, although some sandy zones are noted. The locations of the soil borings are shown in Fig. 7. The depth of this soil (unconsolidated zone) appears to average over 40 ft according to the lithologic logs (Appendix A). The soil-rock interface will typically be highly irregular because of selective weathering of strata with a variable range of lithologic characteristics (i.e., chert content, interbedded limestone or sandstone, etc.).

2.2.1.4 Structure

Structural measurements indicate that the bedrock strata in this area dip uniformly to the southeast at ~30° to 40°; the strike of the dipping beds is northeast–southwest. No other structural trends are evident in the immediate vicinity of the K-1070-A area. The fractures noted in the well logs are the result of stresses induced during periods of regional folding and faulting. The presence of solution cavities indicates some degree of karst or prekarst development.

2.2.2 Hydrology

2.2.2.1 Groundwater

The characterization of groundwater in the K-1070-A area is supported by nine groundwater monitoring wells in the vicinity of the K-1070-A Burial Ground: four bedrock wells ((BRW-5, -6, -25, and -26), two unconsolidated characterization wells (UNW-31 and -32), and three piezometers (UNP-12, -14, and -15). The locations of the unconsolidated zone wells (including piezometers) are shown in Fig. 6, and those of the bedrock monitoring wells are indicated in Fig. 8. These wells were installed according to the *ORGDP Groundwater Protection Program Management Plan.*[17] Water-level measurements by Geraghty & Miller (1989) show the flow direction of groundwater to be generally southward in both the unconsolidated zone and bedrock aquifers, as indicated in Figs. 6 and 8.[14]

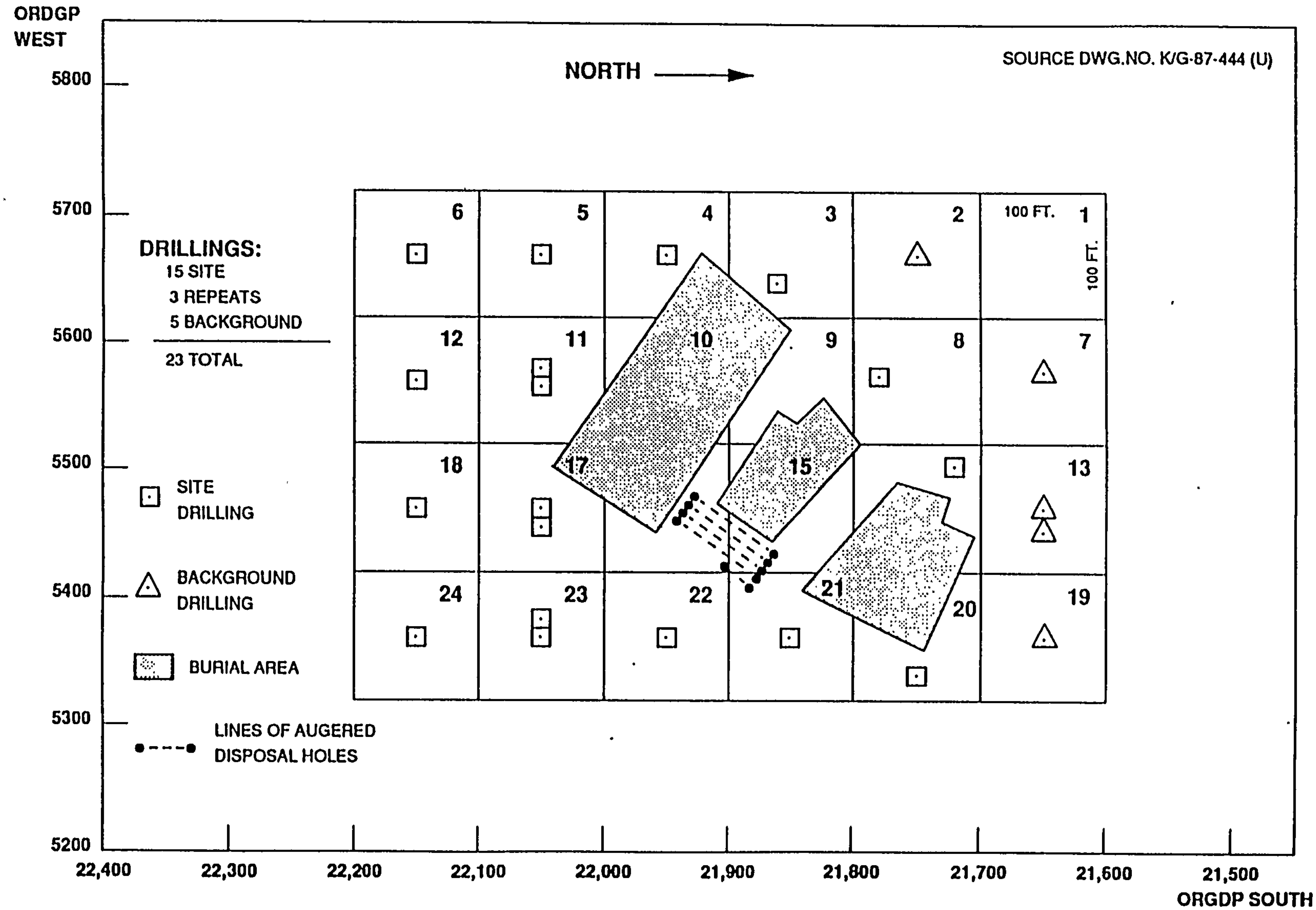


Fig. 7. Location of the soil borings at K-1070-A.

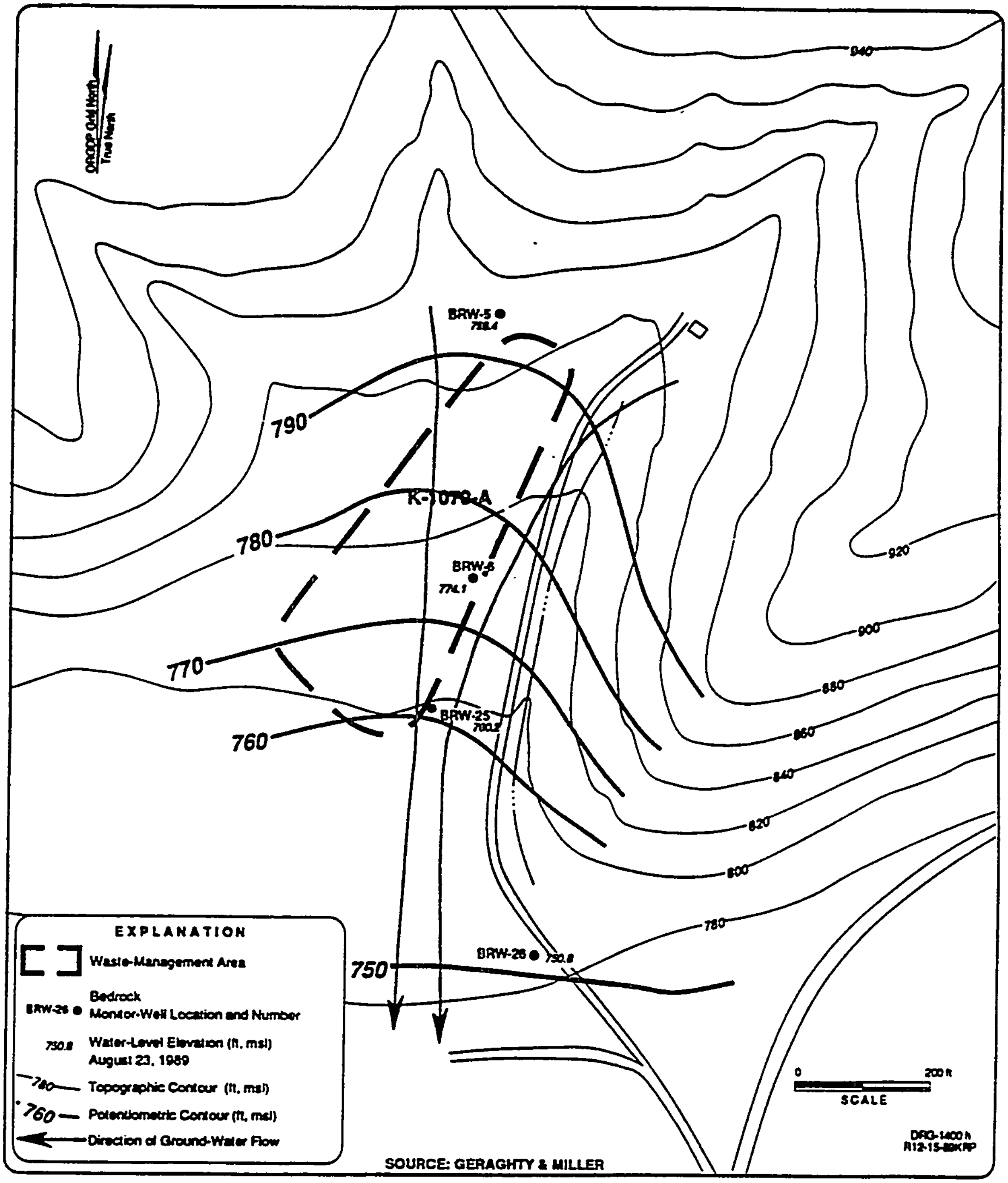


Fig. 8. Location of bedrock monitoring wells at K-1070-A.

The unconsolidated zone stores groundwater and sustains flow within the intergranular pore space. The soil zone here, because of its clayey nature, will transmit water at a considerably slower rate than the bedrock aquifer, and Geraghty & Miller (page 4-9) have reported hydraulic conductivities of 1.1 x 10^{-6}, 1.21 x 10^{-6}, and 2.7 x 10^{-7} cm/s for wells UNP-12, UNP-14, and UNP-15, respectively.[14] These values appear to be typical for the soil material encountered here.

Groundwater storage and flow in the Knox dolomite bedrock mainly occur within a secondary porosity system of interconnecting fractures and joints along bedding planes, all of which are subject to continuous enlargement by the solutional effects of groundwater. Permeability tests reported by Geraghty & Miller (1989) indicate hydraulic conductivities of 5.02 x 10^{-5} and 2.03 x 10^{-4} cm/s for wells BRW-5 and BRW-6, respectively.[14] However, because permeability tests in fractured competent rock are highly dependent on whether or not the tested interval intersects one or more water-bearing cavities, the results are likely to be lower than the actual hydraulic conductivity of the unit. Results from tests elsewhere in the K-25 Site area suggest that the hydraulic conductivity of this formation ranges from 10^{-3} to 10^{-4} cm/s.

A downward vertical hydraulic gradient exists between the unconsolidated and bedrock zones at K-1070-A. This is indicated by the soil borings and by water-level measurements reported by Geraghty & Miller (1989) during the period from December 1985 to August 1989 as shown in Fig. 6 and Fig. 8.[14] Midway along the southeast side of the site, near BRW-6 and UNP-12, the water table in the soil zone is over 5 ft above the indicated potentiometric surface in bedrock (779.5 and 774.1 ft above MSL, respectively). About 200 ft to the south, at BRW-25 and UNW-31, the two water levels begin to merge, and further to the southeast, at wells BRW-26 and UNW-32, the potentiometric surface of the bedrock aquifer is above the water table of the soil zone (at 750.8 and 750.4 ft above MSL, respectively). It is apparent by comparing the water "surfaces" represented in Figs. 6 and 8 that over most of the K-1070-A site the unconsolidated zone has potential to discharge to the bedrock aquifer. Figure 9 is a generalized cross-section that illustrates the hydrogeologic conditions and particularly the relationship of the two groundwater zones across K-1070-A.

Recharge of the unconsolidated zone at K-1070-A is by the infiltration of rainfall into the soil; therefore, because of the potential for a downward flow component over most of the site, the possibility exists for certain contaminants to be carried into the bedrock aquifer. The bedrock aquifer is recharged to some extent from the unconsolidated zone over much of this site; however, most of the recharge for this aquifer probably occurs at higher elevations on Blackoak Ridge to the north and northwest of the site. In such a lithology, it is likely for sinks to exist near the crest and on the southeast slopes of the ridge, which will enhance the recharge potential of the bedrock aquifer.

2.2.2.2 Surface Drainage

There are no perennial streams or springs on or adjacent to K-1070-A, and the only surface water occurrence is from precipitation. Runoff from the site flows with the existing slopes toward the south and southwest into the man-made gully around most of the site, which then drains into the K-901-A Holding Pond, and eventually into the Clinch River. Figure 10 illustrates the general flow paths of surface water in the K-1070-A area.

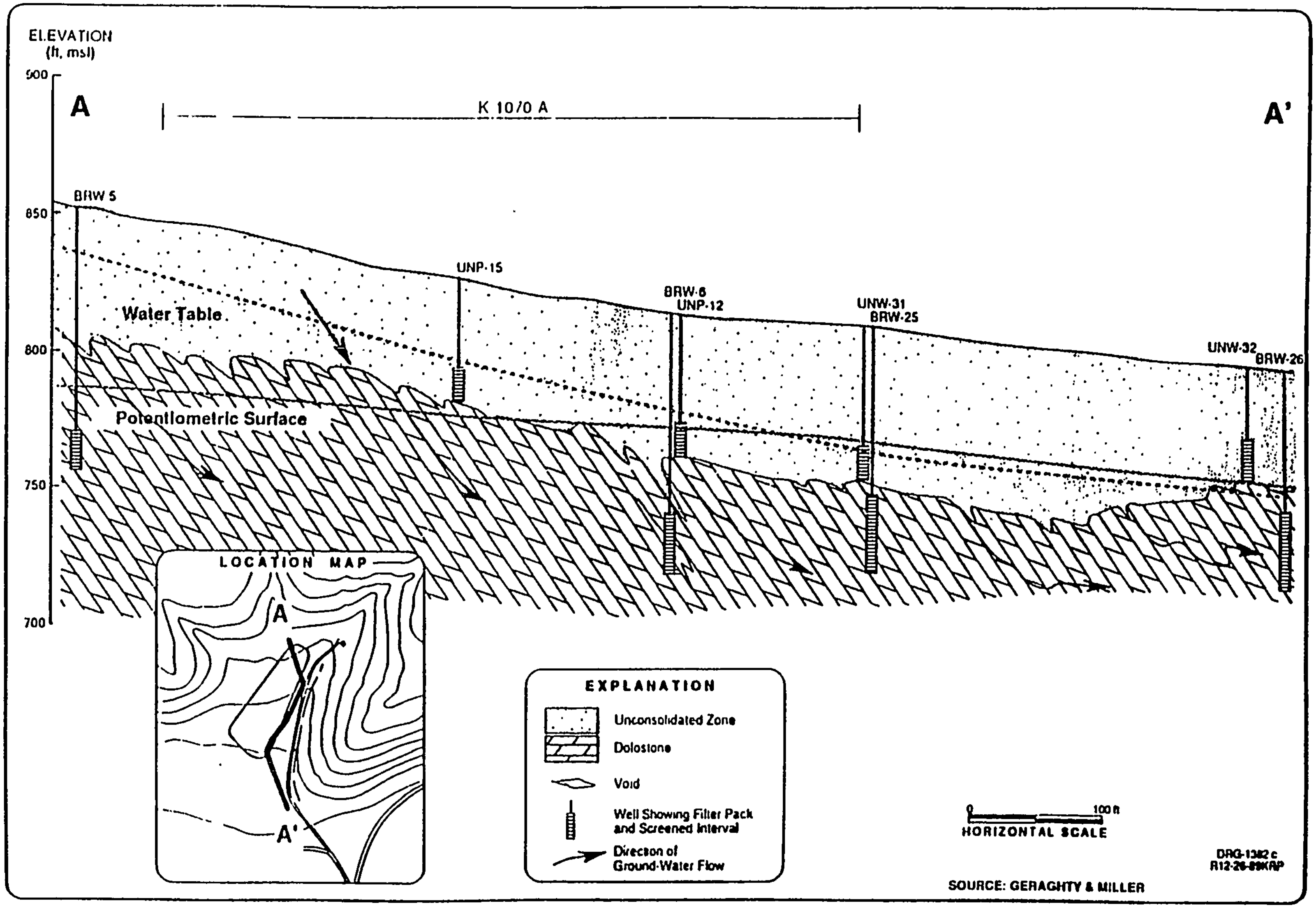


Fig. 9. Generalized cross-section of the K-1070-A area.

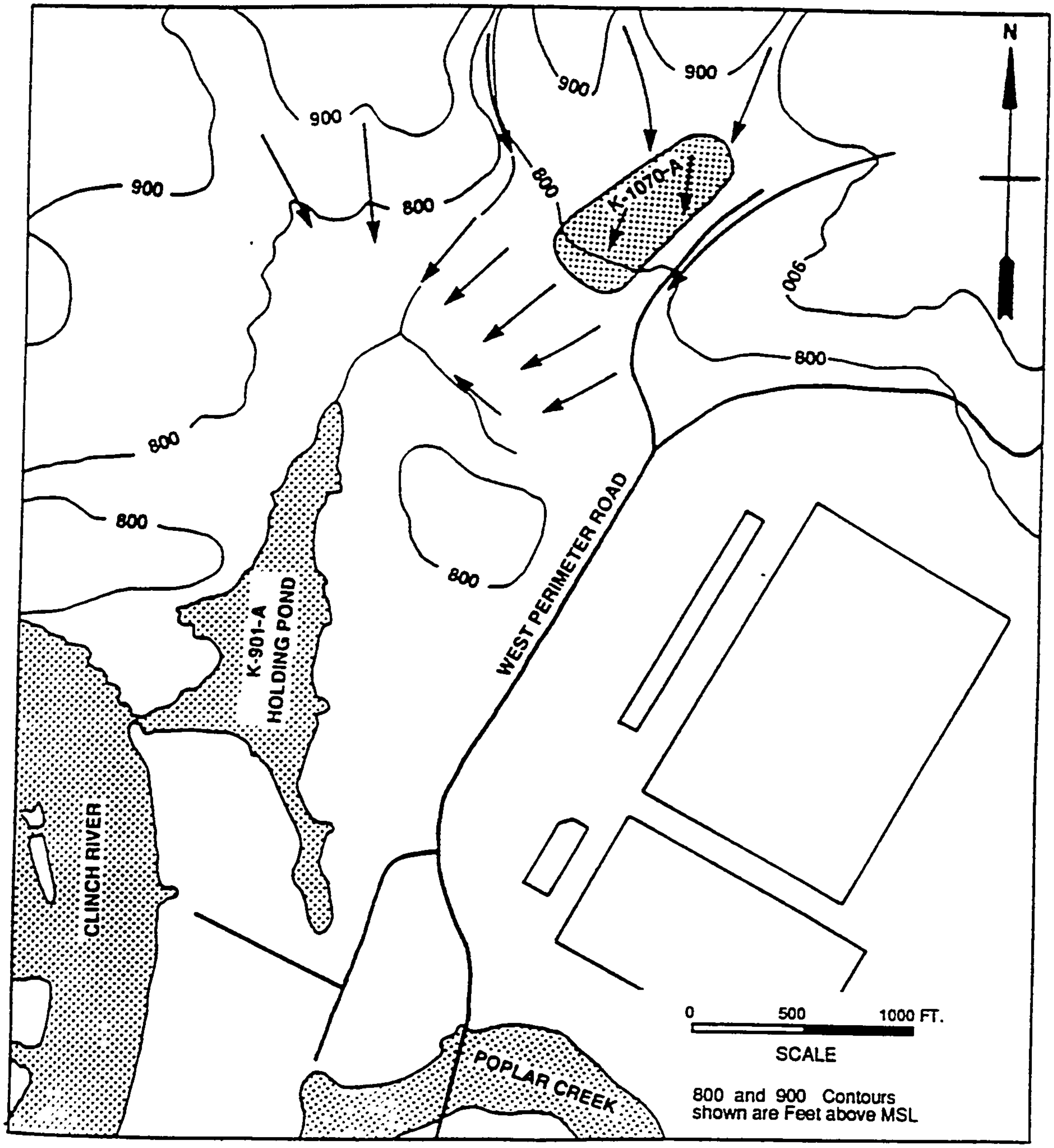


Fig. 10. General flow paths of surface water in the K-1070-A area.

2.2.3 Conclusions and Data Limitations Related to Physical Characterization

The physical characterization of the site suggests groundwater as the predominant route of contaminant migration from the K-1070-A Contaminated Burial Ground. The downward hydraulic gradient indicated by hydrostatic head measurements of the unconsolidated and bedrock zones demonstrates a viable groundwater pathway. Additionally, the contrast in the hydraulic conductivity between the unconsolidated and bedrock zones may serve to assist in the transport of soil contamination to the groundwater. Additionally, contaminants which are believed to have originated at the site have been detected in K-1070-A area groundwater. The major contaminants detected in groundwater are 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, 1,2-dichloroethene, and trichloroethene.

Several data gaps limit the physical characterization of the site. To quantify the migration potential of contaminants via groundwater, soil parameters influencing transport, such as particle-size distribution, porosity, soil pH, oxidation-reduction potential, cation exchange capacity, mineralogy, and organic carbon fraction must be determined. None of these parameters are available for the unconsolidated material at the burial ground. Additionally, the lack of regional concentration ranges for indigenous metal in soil limits the differentiation of site-related metal contamination from natural levels. A comprehensive examination of the range of naturally occurring metal concentrations in Knox residuum has been undertaken by the Oak Ridge Reservation Hydrology and Geology Study.

2.3 OPERATIONAL AND HISTORICAL INFORMATION

The K-1070-A Contaminated Burial Ground was opened in 1948 or 1949 and was used for the disposal of unclassified low-level radioactive solid and mixed chemical wastes. The wastes were emptied into augured holes and trenches or buried in drums. Accurate up-to-date records of the materials disposed of were kept by marking each disposal area with a numbered stake and correlating those numbers with records of the contents. The disposal records are maintained by the Environmental Management Department of the Health, Safety, and Environmental Affairs Division. The inventory of material buried at the site is included in Appendix B. The majority of the material disposed of in the trenches consisted of leached alumina containing small quantities of uranium, other uranium compounds, thorium compounds, contaminated uranium hexafloride cylinders, beryllium chips, boron, radioactively contaminated sodium fluoride, oil, and rags. It is estimated that ~33,575 ft^3 of uranium-contaminated material and 2430 ft^3 of thorium-contaminated material was buried at the site.

Distinct burial sections, occupying a total of ~0.2 acre, are located within the K-1070-A Contaminated Burial Ground site. The area consists of 62 sections of various sizes, ranging from augured holes 12 ft deep by 3 ft in diameter to trenches 11 ft deep, 3 ft wide, and 108 ft long. Figure 11 shows the locations of these sections within K-1070-A.

The K-1070-A Contaminated Burial Ground was closed in March 1976. At that time, 4 ft of soil was placed over the site, and the area was seeded. The soil cap does not contain surface water diversion or a leachate collection system. Additional history and operational information is contained in the Appendix of the site-specific RFI Plan.[5]

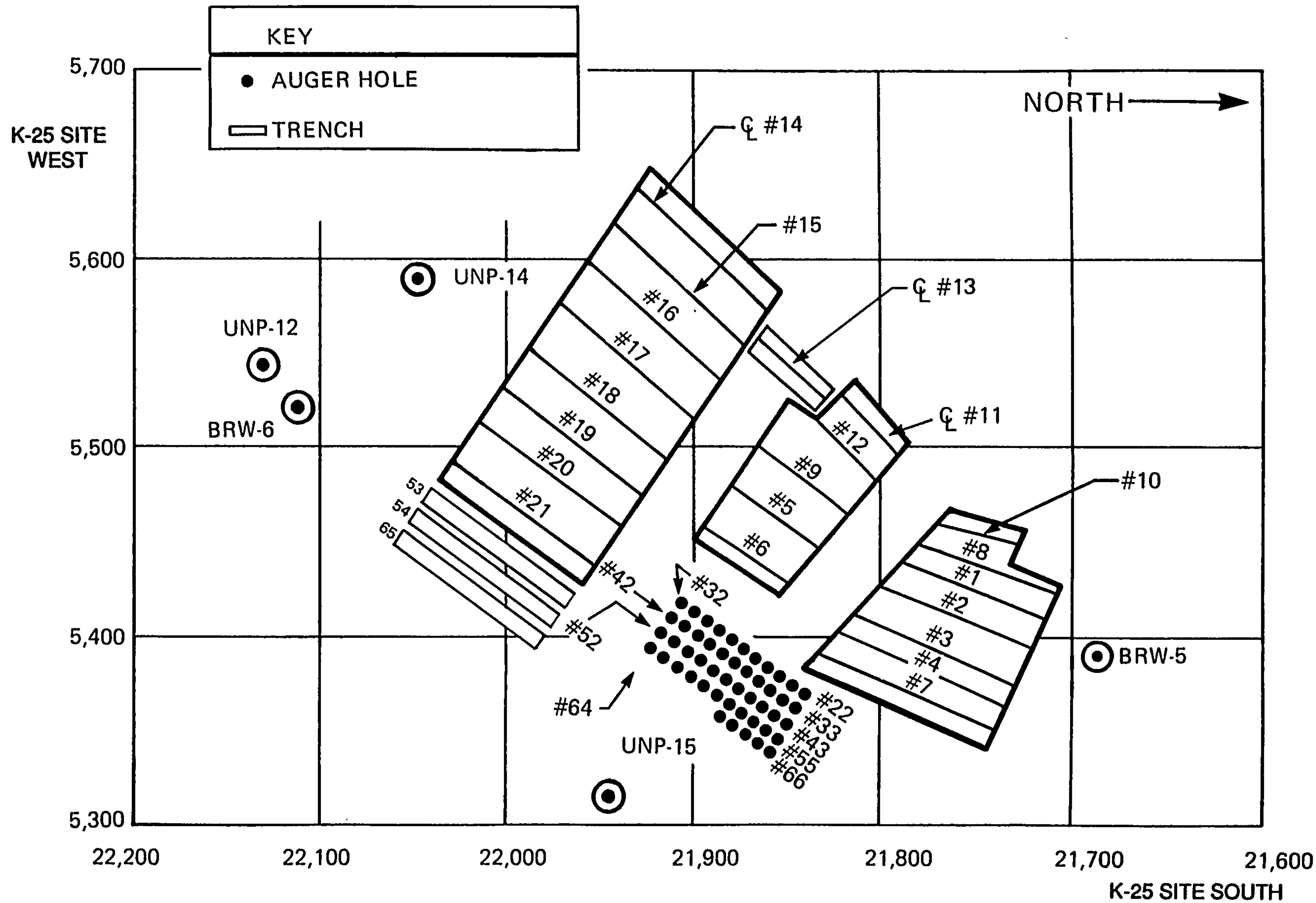


Fig. 11. Location of burial sections at the K-1070-A Contaminated Burial Ground.

3. FIELD INVESTIGATION

3.1 SAMPLING

The investigation of soil contamination at the K-1070-A Contaminated Burial Ground was initiated by soil sampling performed from January to April of 1989. Sample collection followed American Society for Testing and Materials Method D 1586-84. A detailed narrative of field sampling practices is supplied in the *Field Observation Report for K-1070-A Contaminated Burial Ground RCRA Facility Investigation* (K/ER-7).[6] Sampling locations were based on a grid (Fig. 12) covering an area of 400 ft × 600 ft, consisting of 24 cells, each 100 ft × 100 ft. Samples were taken from 19 of the 24 sampling grid cells. Samples were not taken from sectors 9, 10, 15, or 16 because of the possibility of drilling into the disposal area and causing a contamination release. Samples were not taken from sector 1, in the northwestern corner of the site, because it was inaccessible. A total of 23 boreholes were drilled, following a randomized drilling order. Of these boreholes, 15 were primary characterization boreholes, 4 were replicate, and 4 were background (boreholes 2, 7, 13, and 19). Soil samples were obtained from each of the 23 borehole locations and were packaged for analyses for metals, semivolatiles, radioactivity, and volatile organics.

Soil samples were obtained from each borehole at 4-ft intervals until refusal was reached, which generally occurred at a depth of 40 to 50 ft. The lithology of each borehole was logged. Borehole logs are presented in Appendix A. Because a 2-ft split-barrel sampler was used, the 4-ft samples were composed of two successive 2-ft samples. However, samples obtained for volatile organic analysis were not composited; instead, samples were screened with a photoionization detector, and samples for analysis were taken from that section of the sample displaying the highest reading.

3.2 DATA LIMITATIONS

It is suspected that sunlight may have caused the isopropyl alcohol used in sample tool decontamination procedure to break down into acetone. Residues of isopropyl alcohol, if transformed into acetone on sampling tools, could cause the contamination of samples with acetone during the sampling process. Additionally, the random sampling order specified in the sampling plan ran contrary to the standard practice of sampling progressively from areas of least suspected contamination to areas of most suspected contamination.

ANALYSIS OF SOILS TO PERFORMED FOR EACH DRILLING LOCATION

a) GROSS ALPHA, BETA, GAMMA, & INORGANIC ELEMENTS
b) VOLATILE ORGANICS
c) SEMI-VOLATILE ANALYSIS (BNAs) (to be composited in the lab)

AMOUNTS OF a AND b ARE AS FOLLOWS

a) 308
b) 84

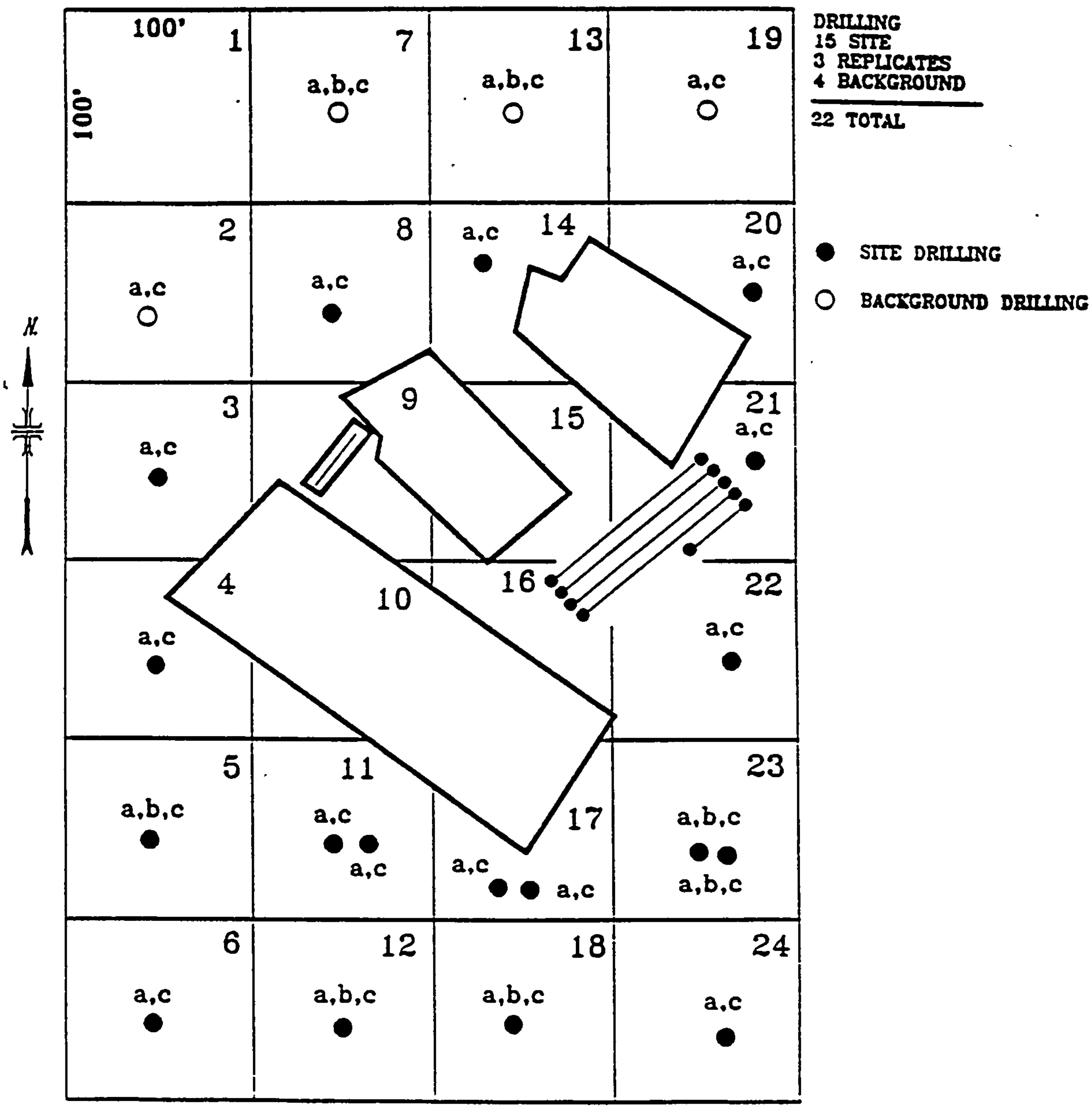


Fig. 12. Grid system for soil sampling activities at K-1070-A.

4. QUALITY ASSURANCE/QUALITY CONTROL

4.1 INTRODUCTION

The data objectives for the K-1070-A Burial Ground are to obtain samples representative of the environment in the vicinity of the site. A review of the inventory of buried material at K-1070-A reveals that the site was used almost exclusively for the burial of metallic and radioactive waste. Consequently, the focus of the sampling at K-1070-A was for metallic and radiochemical contamination. It was further determined, based on the data from area groundwater monitoring wells, that a limited number of samples needed to be collected for volatile organic (VO) analysis. Finally, borehole composites were prepared and analyzed to determine the presence of any gross organic contamination not accounted for in the K-1070-A inventory. Due to the nature of the site, soil was the only medium sampled. In addition to the soil samples, various QA samples were prepared. These samples included equipment rinsates, to determine the adequacy of field cleaning procedures; field blanks, to assure that water used in the field was not contaminated; and duplicate samples, to assess the reproducibility of the field sampling. The samples were collected, prepared, and shipped following accepted EPA methodology. The analyses were also performed according to accepted EPA protocol, which is discussed in the following text.

4.2 ANALYTICAL METHODOLOGY

All samples from the K-1070-A Contaminated Burial Ground were analyzed by the Analytical Chemistry Department of the K-25 Site. Table 1 is a summary of the number and the types of analyses performed on samples as part of the K-1070-A Contaminated Burial Ground investigation. Table 2 is a summary of the analytical methodology used for samples from this site and described in Sects. 4.2.1 through 4.2.4.

4.2.1 Inorganic Analysis

As stated in Sect. 4.1, the presence of metallic contamination was a major concern at the K-1070-A site. All core samples (as defined in the site-specific RFI Plan)[5] and all QA samples were analyzed for metallic contamination. Apart from mercury, the volatile metallic elements (As, Se, and Pb) were not of primary concern; therefore, EPA-6010 (SW-846) was utilized for the characterization of all metals of concern as defined in the site-specific RFI Plan.[5] Mercury was determined utilizing EPA-7471 and SW-846.

4.2.2 Radiochemical Analysis

Radiochemical contamination was determined to be a major concern, and therefore all soil samples (as defined in the site-specific RFI Plan)[5] were analyzed for gross alpha, beta, and gamma radiation. All QA samples were also analyzed for radiation. The aqueous QA samples (equipment rinsates and field blanks) were preserved by lowering the pH of the

Table 1. Summary of K-1070-A analyses (no. of samples)

Analysis	Soil: Sample	Soil: Duplicate	Soil: Matrix spike	Soil: Matrix spike duplicate	Water: Rinsate	Water: Field blank	Water: Matrix spike
				Inorganic			
ICP metals	213	22	15	0	24	8	0
Mercury	213	22	19	0	24	8	10
				Radiochemical			
Radiochemical	213	22	12	0	24	8	0
				Organic			
Semivolatile	24	0	0	0	24	8	0
Volatile	61	0	6	6	7	3	0

Table 2. Analytical methodologies

Analyte	Methodology
Inorganic	
ICP metals (including As, Se, and Pb)	EPA-6010 (SW-846)
Mercury	EPA-7471 (SW-846)
Radiochemical	
Alpha, beta	EPA-900.0
Gamma	EC-134
Organic	
Volatile organic	Per EPA Contract Laboratory Program (CLP) Statement of Work (SOW) for organics analysis February 1988
Semivolatile organic	EPA-3540 (SW-846) preparation analysis per EPA CLP SOW for organics analysis (February 1988)

sample to <2.0 using HNO_3. Gross alpha, beta, and gamma analyses were performed in order to characterize the radiochemical contamination. QC for the radiochemical characterization included routine calibration, measurement of instrument and methodology blanks, and preparation and analysis of matrix spike samples on a routine basis. Gross alpha and beta analysis was carried out using EPA-900.0. The determination of gross gamma levels was performed using EC-134. All aqueous samples were also analyzed according to these methods. Soil samples underwent an initial nitric acid leach. Both EC-134 and the soil leach procedure are described in Appendix A of the General Document.[4]

4.2.3 Volatile Organic Analysis

Trace amounts of VO contamination were detected during the development of groundwater monitoring wells in the K-1070-A area. A select number of samples were thus taken for VO analysis. All QA samples were also analyzed for VOs. Liquid samples were preserved using hydrochloric acid and cooling. Analyses were carried out under Contract Laboratory Program (CLP) protocol (EPA CLP Statement of Work, February 1988).

4.2.4 Semivolatile Organic Analysis

As outlined in the *RCRA Facility Investigation Plan*,[5] borehole composites were prepared for each borehole after sample log-in and were analyzed for semivolatile organics. All QA samples were also analyzed for semivolatile organics. Preparation of soil samples was performed using EPA-3540 (SW-846). Analysis of the resulting extract was performed using capillary column gas chromatography/mass spectrography operating under CLP protocol (EPA CLP Statement of Work, February 1988). This analysis was not intended for the determination of Target Compounds (TCs) as defined by CLP protocol because the presence of any significant concentration of CLP TCs was deemed unlikely. Rather, the analysis was utilized as a screen for any unexpected gross organic contamination.

4.3 HOLDING TIMES

4.3.1 Inorganic Samples

Samples analyzed for metals by inductively coupled plasma have holding times of 6 months; none of the samples exceeded holding time limitations. Because mercury is a volatile metal, the holding time for samples scheduled for mercury analyses is 28 days. Again, all samples were analyzed within the recognized holding times.

4.3.2 Radiochemical Samples

There are no recognized holding times for radiochemical analyses.

4.3.3 Volatile Organic Samples

The holding time for samples destined for VO analyses is 14 days from the sampling date (SW-846) for soil and aqueous QA samples. Two equipment rinsates and a duplicate equipment rinsate were the only samples analyzed after holding times had elapsed. The samples exceeding holding times are shown in Table 3.

Table 3. Volatile organic analyses exceeding holding times

Sample	Sample type	Holding time
BH007ASE09	Equipment rinsate	20 days
BH007ASE09	Duplicate equipment rinsate	20 days
BH005ASE24	Equipment rinsate	15 days

4.3.4 Semivolatile Organic Samples

There are two holding times associated with semivolatile organic analyses. There is a holding time of 14 days within which time the extraction of the sample must be completed. All samples were extracted within the 14 days allotted. Additionally, the extracts need to be analyzed within 40 days. Again, all K-1070-A Contaminated Burial Ground samples were analyzed within this time period.

4.4 EQUIPMENT RINSATES

Equipment rinsates are QA samples designed to determine the cleanliness of equipment used for sampling. These samples are generally water samples obtained by washing equipment with clean water immediately after the completion of the cleaning process. These samples should be preserved according to EPA guidelines for aqueous samples and should be analyzed for all parameters of interest. For samples taken from the K-1070-A Contaminated Burial Ground, the equipment rinsates were analyzed for metals, volatile and semivolatile organics, and radioactivity. The methodologies utilized were identical to those used for the samples.

4.4.1 Inorganic Rinsate Analysis

Analysis of equipment rinsate samples for metallic analytes suggests that sample contamination by sampling equipment is likely only for copper, zinc, and possibly arsenic. For those analytes more than half of the equipment rinsates contained detectable levels of these inorganic constituents. Equipment rinsate, field blank, and sample data for these three elements are presented in Figs. 13 through 15. The sample log correlating the sample order number in the figures is presented in Table 4.

4.4.2 Radiochemical Rinsate Analysis

The equipment rinsate data and sample data for gross alpha (Fig. 16) and gross beta (Fig. 17) indicate significant contamination during the early portion of the field investigation. The sample log correlating samples to sample order numbers is presented in Table 4. In addition to both being contaminated, the relative alpha/beta activity remains constant, indicating the likelihood of a single radioisotope contaminant. The source of this contamination is presently unexplained. Based on analysis of the figures, it does not appear as though the contamination found in the equipment rinsate had a significant impact on the results. During the time period when the equipment rinsate had the highest level of contamination (the first equipment rinsate) the samples were found to have the lower activity measurements.

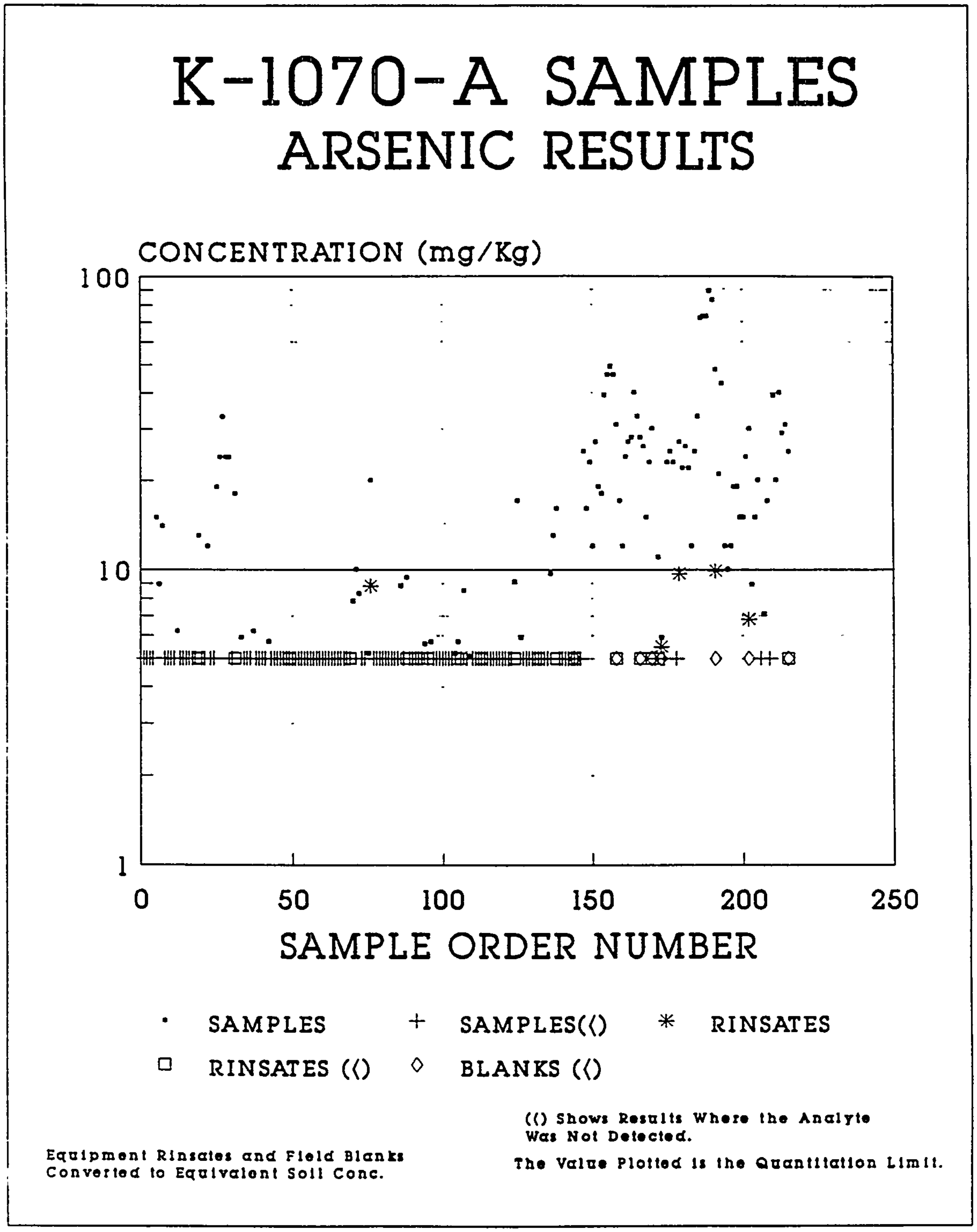


Fig. 13. Comparison of arsenic in rinsates, blanks, and samples.

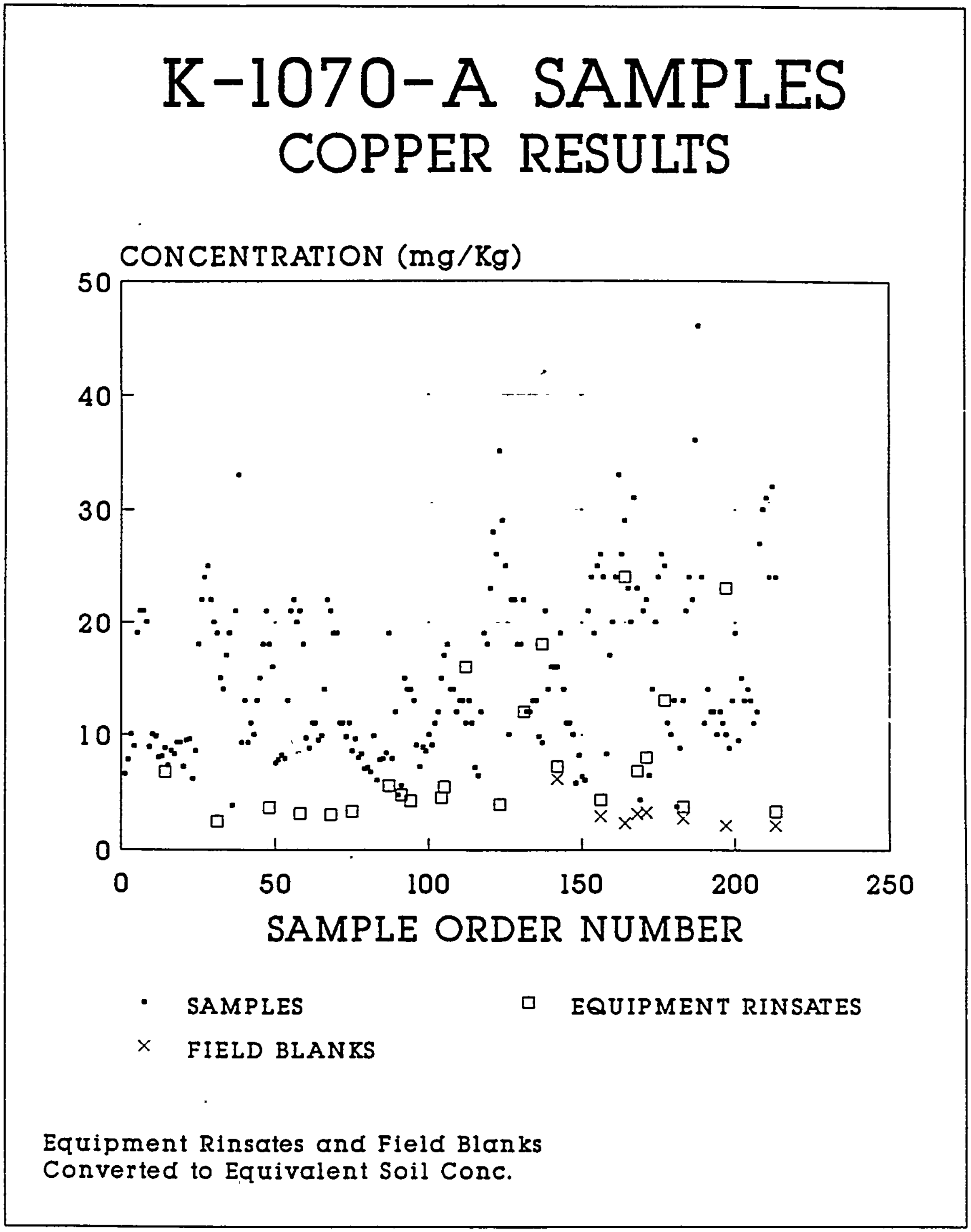


Fig. 14. Comparison of copper in rinsates, blanks, and samples.

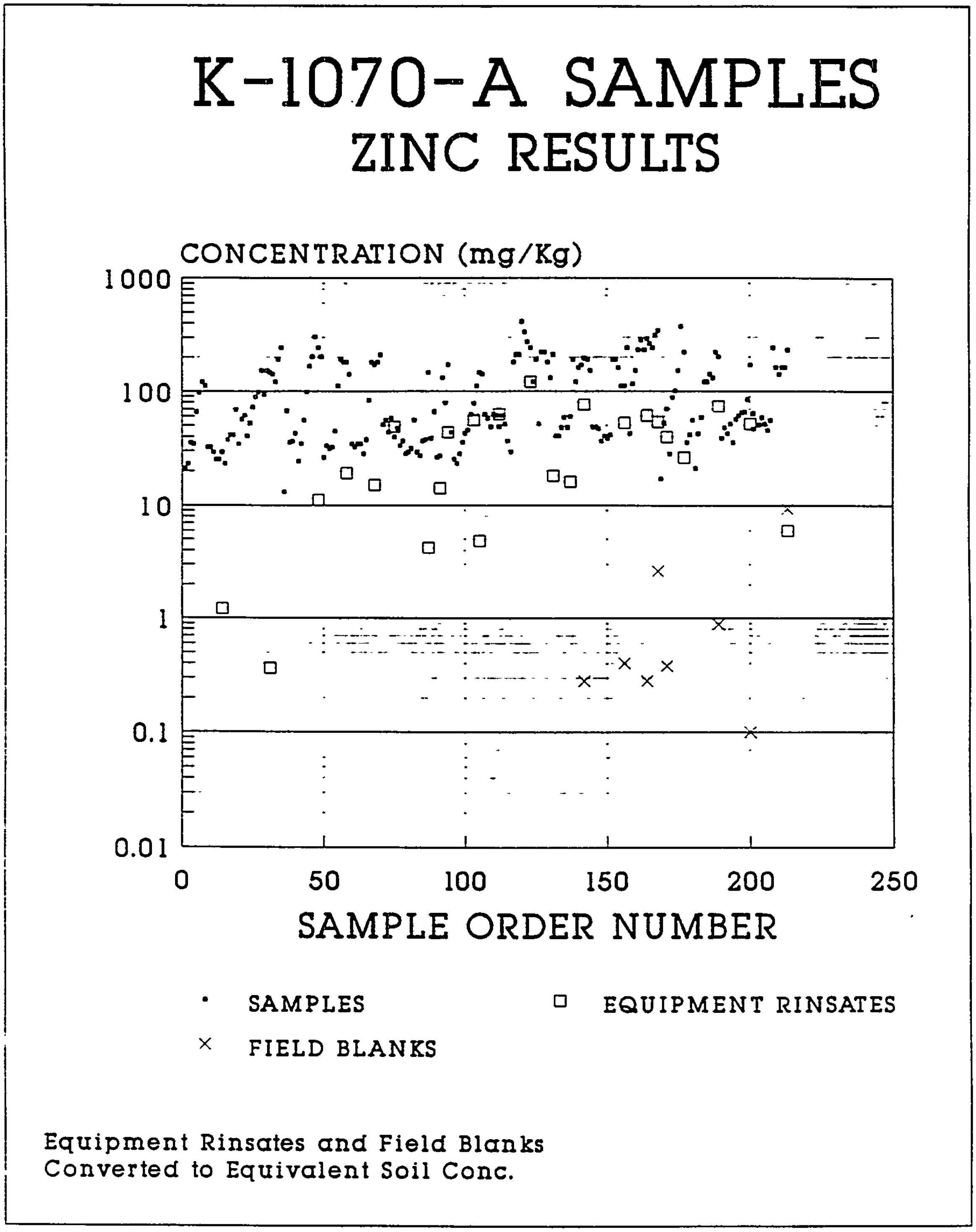


Fig. 15. Comparison of zinc in rinsates, blanks, and samples.

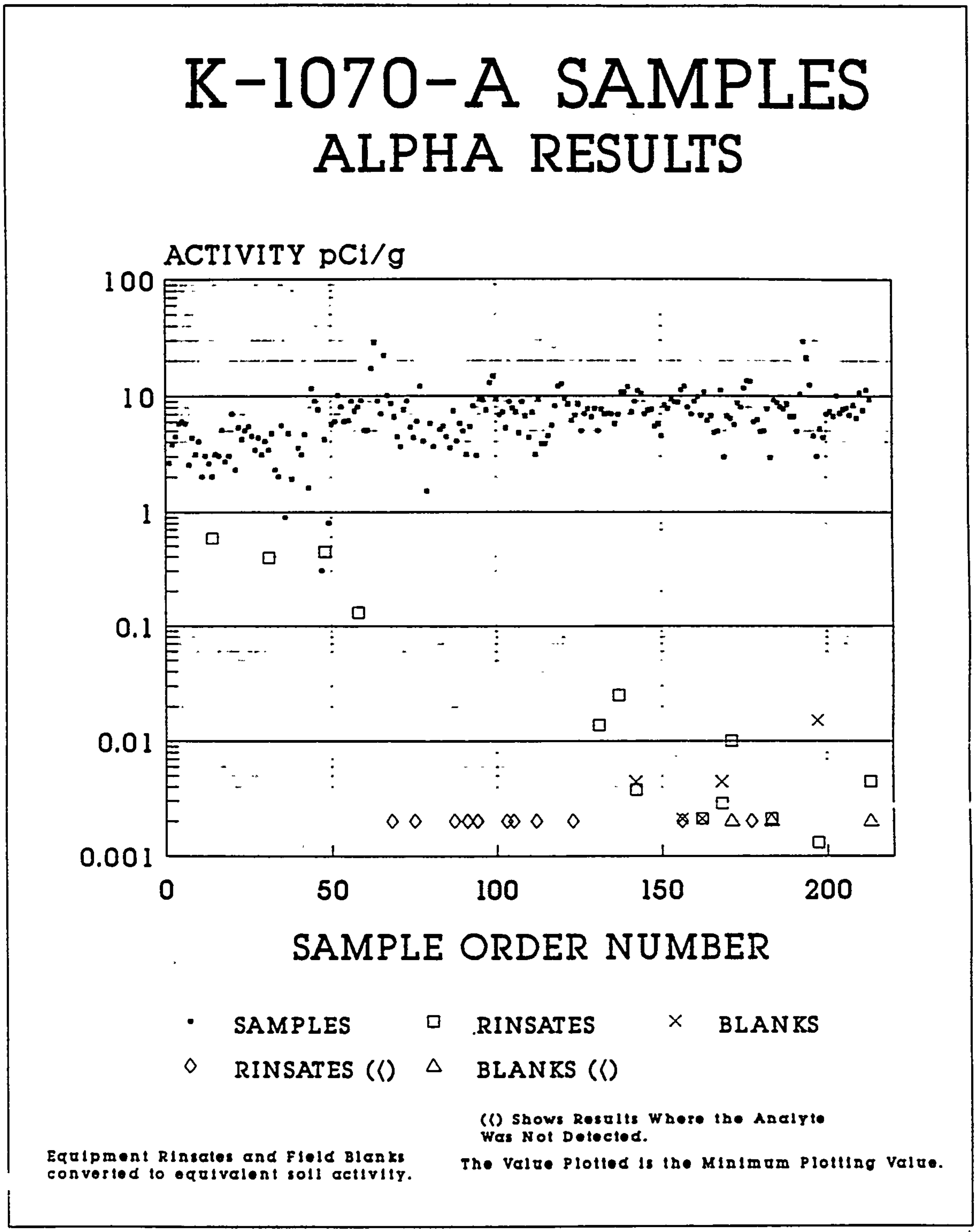


Fig. 16. Comparison of gross alpha radiation in rinsates, blanks, and samples.

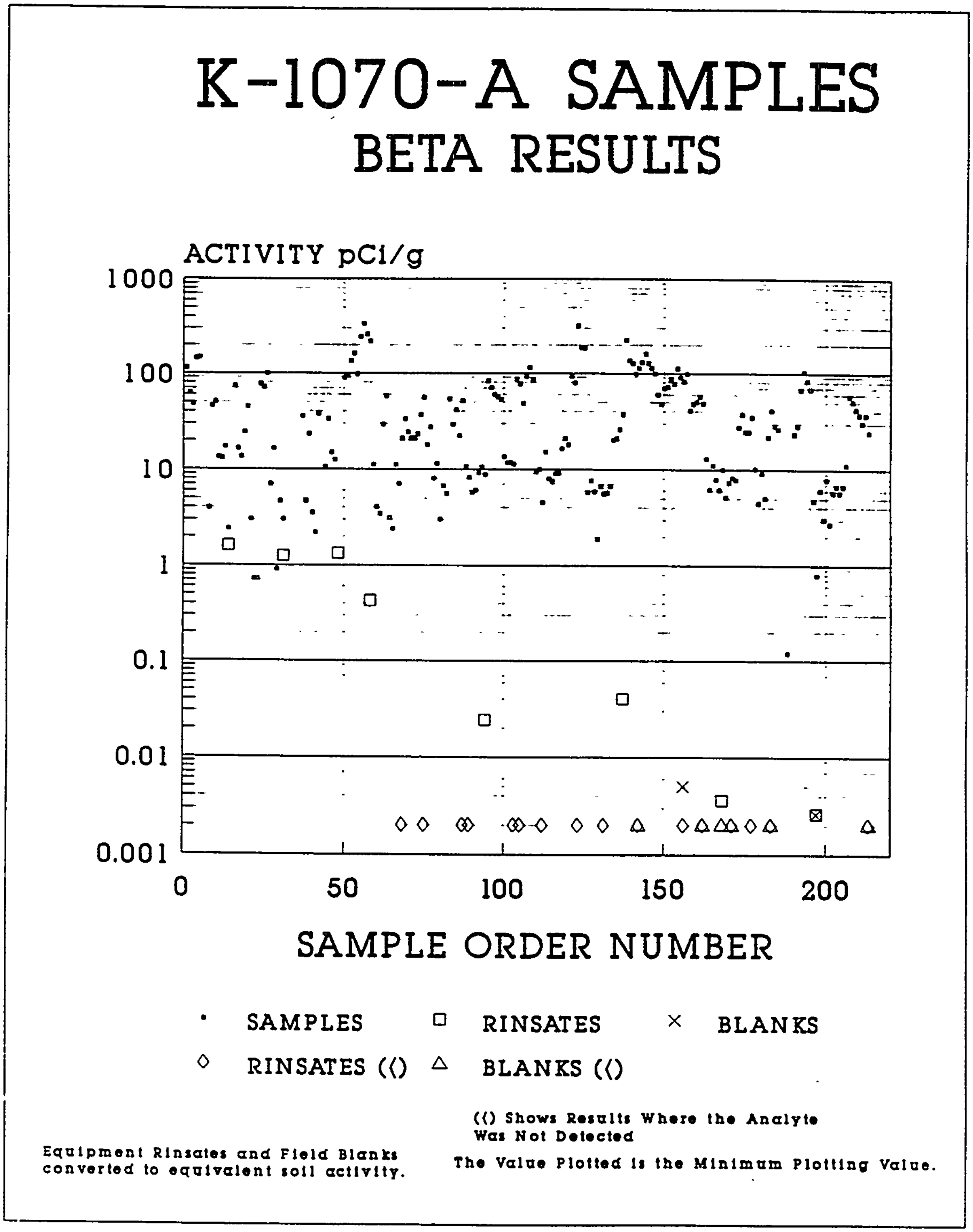


Fig. 17. Comparison of gross beta radiation in rinsates, blanks, and samples.

Table 4. Inorganic analysis sample log

Order number	Customer number	Grid location[a]	Sample depth (ft)[b]
1	BH18SO0118904B	18	4
2	BH18SO0118908B	18	8
3	BH18SO0118912B	18	12
4	BH18SO0118916B	18	16
5	BH18SO0118920B	18	20
6	BH18SO0118924B	18	24
7	BH18SO0119928B	18	28
8	BH18SO0119931B	18	31
9	BH12SO0119904B	12	4
10	BH12SO0119908B	12	8
11	BH12SO0119912B	12	12
12	BH12SO0119916B	12	16
13	BH12SO0119920B	12	20
14	BH12SO0119924B	12	24
15	BH12SO0119928B	12	28
16	BH12SO0119932B	12	32
17	BH12SO0120936B	12	36
18	BH12SO0120940B	12	40
19	BH12SO0120941B	12	41
20	BH24SO0120904B	24	4
21	BH24SO0120908B	24	8
22	BH24SO0120912B	24	12
23	BH24SO0120916B	24	16
24	BH24SO0120920B	24	20
25	BH24SO0120924B	24	24
26	BH24SO0120928B	24	28
27	BH24SO0120932B	24	32
28	BH24SO0120936B	24	36
29	BH24SO0120940B	24	40
30	BH24SO0120944B	24	44
31	BH24SO0121948B	24	48
32	BH24SO0121952B	24	52
33	BH24SO0121956B	24	56
34	BH24SO0121960B	24	60
35	BH24SO0121962B	24	62
36	BH13SO0122904B	13	4
37	BH13SO0122908B	13	8
38	BH13SO0122912B	13	12
39	BH21SO0123904B	21	4
40	BH21SO0123908B	21	8
41	BH21SO0123912B	21	12
42	BH21SO0123916B	21	16
43	BH21SO0123920B	21	20
44	BH21SO0123924B	21	24
45	BH21SO0123928B	21	28
46	BH21SO0123932B	21	32
47	BH21SO0123936B	21	36
48	BH21SO0123940B	21	40

Table 4. Inorganic analysis sample log (continued)

Order number	Customer number	Grid location[a]	Sample depth (ft)[b]
49	BH21SO0123942B	21	42
50	BH11ASO0131904	11	4
51	BH11ASO0131908	11	8
52	BH11ASO0131912	11	12
53	BH11ASO0131916	11	16
54	BH11ASO0131920	11	20
55	BH11ASO0131924	11	24
56	BH11ASO0131928	11	28
57	BH11ASO0131932	11	32
58	BH11ASO0131936	11	36
59	BH11ASO0131938	11	38
60	BH11BSO0201904	11	4
61	BH11BSO0201908	11	8
62	BH11BSO0201912	11	12
63	BH11BSO0201916	11	16
64	BH11BSO0201920	11	20
65	BH11BSO0201924	11	24
66	BH11BSO0201928	11	28
67	BH11BSO0201932	11	32
68	BH11BSO0201936	11	36
69	BH11BSO0201940	11	40
70	BH11BSO0201942	11	42
71	BH06BSO0202904	6	4
72	BH06BSO0202908	6	8
73	BH06BSO0202912	6	12
74	BH06BSO0202916	6	16
75	BH06BSO0202920	6	20
76	BH06BSO0202924	6	24
77	BH06BSO0202928	6	28
78	BH06BSO0202932	6	32
79	BH06BSO0202936	6	36
80	BH06BSO0202940	6	40
81	BH06BSO0202944	6	44
82	BH06BSO0202948	6	48
83	BH14SO0222904B	14	4
84	BH14SO0222908B	14	8
85	BH14SO0222912B	14	12
86	BH14SO0222916B	14	16
87	BH14SO0222920B	14	20
88	BH07SO0301904B	7	4
89	BH07SO0301908B	7	8
90	BH02SO0301904B	2	4
91	BH02SO0301908B	2	8
92	BH02SO0301912B	2	12
93	BH02SO0301916B	2	16
94	BH02SO0301920B	2	20
95	BH17ASO0302904	17	4
96	BH17ASO0302908	17	8
97	BH17ASO0302912	17	12

Table 4. Inorganic analysis sample log (continued)

Order number	Customer number	Grid location[a]	Sample depth (ft)[b]
98	BH17ASO0302916	17	16
99	BH17ASO0302920	17	20
100	BH17ASO0302924	17	24
101	BH17ASO0302928	17	28
102	BH17ASO0302932	17	32
103	BH17ASO0302936	17	36
104	BH17ASO0302940	17	40
105	BH17ASO0303944	17	44
106	BH17ASO0303946	17	46
107	BH05SO0306904B	5	4
108	BH05SO0306908B	5	8
109	BH05SO0306912B	5	12
110	BH05SO0306916B	5	16
111	BH05SO0306920B	5	20
112	BH05SO0306924B	5	24
113	BH05SO0306928B	5	28
114	BH05SO0306932B	5	32
115	BH20SO0307904B	20	4
116	BH20SO0307908B	20	8
117	BH20SO0307912B	20	12
118	BH20SO0307916B	20	16
119	BH20SO0307920B	20	20
120	BH20SO0307924B	20	24
121	BH20SO0307928B	20	28
122	BH20SO0307932B	20	32
123	BH20SO0307936B	20	36
124	BH20SO0307940B	20	40
125	BH20SO0308944B	20	44
126	BH08SO0329904B	8	4
127	BH08SO0329908B	8	8
128	BH08SO0329912B	8	12
129	BH08SO0329916B	8	16
130	BH08SO0329920B	8	20
131	BH08SO0329924B	8	24
132	BH22SO0330904B	22	4
133	BH22SO0330908B	22	8
134	BH22SO0330912B	22	12
135	BH22SO0330916B	22	16
136	BH22SO0330920B	22	20
137	BH22SO0330924B	22	24
138	BH22SO0403932B	22	32
139	BH22SO0403936B	22	36
140	BH22SO0403940B	22	40
141	BH22SO0403944B	22	44
142	BH22SO0403948B	22	48
143	BH22SO0403952B	22	52
144	BH22SO0403956B	22	56
145	BH23ASO0405904	23	4
146	BH23ASO0405908	23	8

Table 4. Inorganic analysis sample log (continued)

Order number	Customer number	Grid location[a]	Sample depth (ft)[b]
147	BH23ASO0405912	23	12
148	BH23ASO0405916	23	16
149	BH23ASO0405920	23	20
150	BH23ASO0405924	23	24
151	BH23ASO0405928	23	28
152	BH23ASO0405932	23	32
153	BH23ASO0405936	23	36
154	BH23ASO0405940	23	40
155	BH23ASO0405944	23	44
156	BH23ASO0405948	23	48
157	BH23ASO0406952	23	52
158	BH03ASO0406904	3	4
159	BH03ASO0406908	3	8
160	BH03ASO0406912	3	12
161	BH03ASO0406916	3	16
162	BH03ASO0406920	3	20
163	BH03ASO0406924	3	24
164	BH03ASO0406928	3	28
165	BH03ASO0407932	3	32
166	BH03ASO0407936	3	36
167	BH03ASO0407940	3	40
168	BH03ASO0407944	3	44
169	BH13BSO0410904	13	4
170	BH13BSO0410908	13	8
171	BH13BSO0410912	13	12
172	BH19ASO0410904	19	4
173	BH19ASO0410908	19	8
174	BH19ASO0410912	19	12
175	BH19ASO0410916	19	16
176	BH19ASO0410920	19	20
177	BH19ASO0410924	19	24
178	BH23BSO0411904	23	4
179	BH23BSO0411908	23	8
180	BH23BSO0411912	23	12
181	BH23BSO0411916	23	16
182	BH23BSO0411920	23	20
183	BH23BSO0411924	23	24
184	BH23BSO0411928	23	28
185	BH23BSO0411932	23	32
186	BH23BSO0411936	23	36
187	BH23BSO0411940	23	40
188	BH23BSO0411944	23	44
189	BH23BSO0411948	23	48
190	BH17BSO0413904	17	4
191	BH17BSO0413908	17	8
192	BH17BSO0413912	17	12
193	BH17BSO0413916	17	16
194	BH17BSO0413920	17	20
195	BH17BSO0413924	17	24

Table 4. Inorganic analysis sample log (continued)

Order number	Customer number	Grid location[a]	Sample depth (ft)[b]
196	BH17BSO0413928	17	28
197	BH17BSO0413932	17	32
198	BH17BSO0413936	17	36
199	BH17BSO0413940	17	40
200	BH17BSO0413944	17	44
201	BH04SO0414904B	4	4
202	BH04SO0414908B	4	8
203	BH04SO0414912B	4	12
204	BH04SO0414916B	4	16
205	BH04SO0414920B	4	20
206	BH04SO0414924B	4	24
207	BH04SO0414928B	4	28
208	BH04SO0414932B	4	32
209	BH04SO0414936B	4	36
210	BH04SO0414940B	4	40
211	BH04SO0414944B	4	44
212	BH04SO0414948B	4	48
213	BH04SO0414952B	4	52

[a]Grid locations are illustrated in Fig. 12.
[b]Sample depth represents the depth at the bottom of the segment.

4.4.3 Volatile Organic Rinsate Analysis

Equipment rinsates destined for VO analysis were only collected during sampling days on which soil VO samples were collected. A total of seven equipment rinsate samples were analyzed for VOs. One of those samples was a duplicate. Table 5 lists the CLP TCs found in the equipment rinsates and summarizes the quantitative results. The presence of these compounds in the equipment rinsates is not expected to have any effect on the interpretation of the results. In addition to the CLP TCs found, a number of tentatively identified compounds (TICs) were also detected. The majority of the TICs found were also detected in the method blank and were eliminated from further consideration. The most obvious of the remaining TICs was isopropyl alcohol (isopropanol, 2-propanol) which is one of the decontamination solutions used.

4.4.4 Semivolatile Organic Rinsate Analysis

Because a single semivolatile sample was prepared for every borehole, every equipment rinsate was analyzed for semivolatile organics, in addition to inorganics and gross alpha, beta, and gamma. Table 5 lists the CLP TCs found in the equipment rinsates and summarizes the quantitative results. Again, in addition to the CLP TCs found, there were a number of TICs detected. Of those detected only in samples, dioctyl adipate was the most notable. In addition there were a number of unknowns, mostly at concentrations <50 μg/L, some alkyl hydrocarbons at <30 μg/L, and unknown siloxanes at <10 μg/L.

Table 5. CLP Target compound summary for equipment rinsates

Compound	Rinsates detected	Maximum (μg/L)	Minimum (μg/L)	Average (μg/L)
Volatile Organics (7 samples analyzed)				
Acetone	5	200	15	71
Bromodichloromethane	7	10	5	6
Chloroform	7	77	35	52
Semivolatile Organics (24 samples analyzed)				
Benzo(a)pyrene[a]	1	3	3	3
Benzo(b)fluoranthene[a]	1	3	3	3
Benzo(k)fluoranthene[a]	1	2	2	2
Di-n-butylphthalate[a]	2	2	0.8	1.4
bis(2-Ethylhexyl)phthalate	4	600[1]	7	159
Di-n-Octylphthalate	2	89	1	45
Butylbenzylphthalate	1	16	16	16
Diethylphthalate	4	0.8	0.3	0.6

[a]Equipment rinse BH014ASE20.

4.5 FIELD BLANKS

During this investigation, field blanks were submitted only near the end of the sampling period. Field blanks were used during the investigation to determine if contamination found in the equipment rinsate resulted from the use of contaminated rinse water. The results of the field blanks are summarized below.

4.5.1 Inorganic Field Blanks

As noted in Sect. 4.4.1, only copper, zinc, and arsenic were detected in the equipment rinsates at levels sufficient to bias sample results. The field blanks for these metals were examined to determine if the copper, zinc, and arsenic concentrations seen in the equipment rinsates were present due to the use of water contaminated with these metals. Comparison of Figs. 13, 14, and 15 indicates that copper, zinc, and arsenic are indeed being rinsed from the cleaned equipment and are not a constituent of the water used in rinsing.

4.5.2 Radiochemical Field Blanks

Field blanks were not submitted for analysis during the period of time when the equipment rinsates showed high alpha and beta activity. Consequently, it is impossible to determine definitively that the contamination seen is not contained in the water being used to rinse the equipment; it is, however, very unlikely. Figs. 16 and 17 include the alpha and beta activity for the field blanks. Within the error range of the methodology being used for analysis, there is no background activity evident in the water being used for equipment rinsates.

4.5.3 Volatile Organic Field Blanks

An analysis of the field blank data can be performed in a manner similar to that of the equipment rinsate analyses. Table 6 summarizes the results for field blanks. A comparison of Tables 5 and 6 shows chloroform and bromodichloromethane at similar concentrations in the equipment rinsates and the field blanks; this leads to the conclusion that the contamination is probably due to the presence of these compounds in the rinse water. Based on the results of field blank analyses, tetrachloroethene is also suspected to be in the rinse water although none was detected in the equipment rinsate samples. Because the level of tetrachloroethene is so low in the field blank samples, it is thought that sufficient volatization occurred during equipment rinsing activity to diminish the level in the rinsate water to concentrations below the detection limit of the analysis.

Table 6. CLP Target compounds summary (VO) for field blanks

Compound	Blanks detected[a]	Maximum (μg/L)	Minimum (μg/L)	Average (μg/L)
Acetone	1/8	10	10	10
Bromodichloromethane	3/8	7	6	6
Chloroform	3/8	45	43	44
Tetrachloroethane	1/8	1	1	1

[a] Number of samples in which analyte was detected/total number of samples.

4.5.4 Semivolatile Organic Field Blanks

The only CLP TC detected in the semivolatile field blanks was di-n-octylphthalate (at an extremely low level, 2 μg/L). It was only detected in two of the eight field blanks submitted for semivolatile analysis. The TICs detected in the field blanks were the same as those detected in the equipment rinsate samples, dioctyl adipate being the most notable.

4.6 MATRIX SPIKE AND SURROGATE SPIKE RECOVERIES

Matrix spikes and surrogate spikes are added to samples which require some form of extraction as a preparation for analysis. Matrix spikes are solutions of known concentrations of specific representative compounds added to samples in specific amounts. Comparison of the measured concentrations of these compounds in the spiked samples and the concentrations in the corresponding original samples is used to determine the effect of the sample matrix on the extraction efficiency. Matrix spike recoveries are calculated by the formula

$$percent\ recovery = \frac{V_s\ minus\ V_o}{L} \times 100$$

where V_s is the measured concentration of the spiked sample, V_o is the measured concentration of the original sample, and L is the concentration of spike added.

Surrogate spikes are solutions of known concentrations of compounds which would not be present in actual samples. These spikes, used only for VO and semivolatile organic analysis, are added to samples in specific amounts, and the concentrations determined by the analyses are used to estimate the overall extraction efficiency of the method. Surrogate spikes are calculated by the formula

$$percent\ recovery = \frac{V_s}{L} \times 100$$

where V_s is the measured concentration of the spiked sample, and L is the concentration of surrogate spike added.

4.6.1 Inorganic and Radiological Matrix Spikes

Table 7 lists the samples used in the preparation of matrix spikes for the inorganic and radiological analyses performed on samples from K-1070-A and assigns a matrix spike number to represent each sample. The matrix spike solution used in the preparation of matrix spikes for metals (except mercury) contained eight elements (Al, Cd, Cr, Cu, Pb, Mn, Ni, and Zn). Recovery of the aluminum matrix spike was not reported because the soil had a very high aluminum content (~1%), and the contribution due to the aluminum matrix spike (~200 mg/kg) would have been negligible. The mercury matrix level was between 0.5 and 1.5 mg/kg for soils and either 0.002 or 0.001 mg/L for the aqueous QA samples. Of the metal matrix spikes, only manganese showed significant deviation from 100% recovery, with some recoveries outside the acceptable limits of 75% to 125% recovery. This deviation is probably the result of the high manganese content of the soils. Although the manganese content was not nearly as high as the aluminum, it generally was in the range of 0.1%, and the normal precision of the measurement would have a significant impact at the concentration of the spike. The manganese matrix spike results are shown in Fig. 18.

A 300 dpm/ml solution of natural uranium was used as the alpha/beta soil spike, and a ^{137}Cs solution was used as the matrix spiking solution for gamma activity. Only the alpha and beta matrix spikes showed significant deviation from 100% recovery. The data are shown in Fig. 19. Matrix spike Number 7 (BH014ASD20) appears to have a higher than normal recovery for alpha and beta. No explanation can be offered for this high recovery.

Table 7. Samples used for matrix spikes[a]

Matrix spike no.	Metals	Mercury[b]	Gross alpha	Gross beta	Gross gamma[b]
1	12/36	18/31	18/31	18/31	18/31
2	13/12	12/28	24/32	24/32	24/20
3	24/36	24/32	21/42	21/42	21/40
4	24/60	24/60	11/32	11/32	11/28
5	11/12	24/48 E	06/12	06/12	14/20
6	06/16	21/16			
7	02/12	21/42	14/20	14/20	14/20
8	17/04	21/40 E			
9	08/16	11/28	02/04	02/04	17/44
10	20/24	11/36 E	20/44	20/44	
11	23/48	11/20			20/36 E
12	03/32	06/04	22/24	22/24	20/44
13	19/20	06/44			
14	17/08	14/20			
15	23/48	14/20 E	23/48	23/48	23/04
16		02/04	19/24	19/24	03/04
17		17/28			
18		17/46	04/52	04/52	04/44
19		05/08			
20		05/32			
21		20/44			
22		20/36 E			
23		08/24			
24		08/24 E			
25		22/24			
26		22/56			
27		23/20			
28		23/48			
29		03/28			
30		03/44 E			
31		13/12			
32		19/24			
33		23/32			
34		23/24			
35		17/12			
36		17/44			
37		17/32 E			
38		04/28			
39		04/52			

[a]Sample identification is shown as grid location/sample depth (depth is the bottom of the segment).
[b]Samples with E are equipment rinsates from the equivalent sample locations.

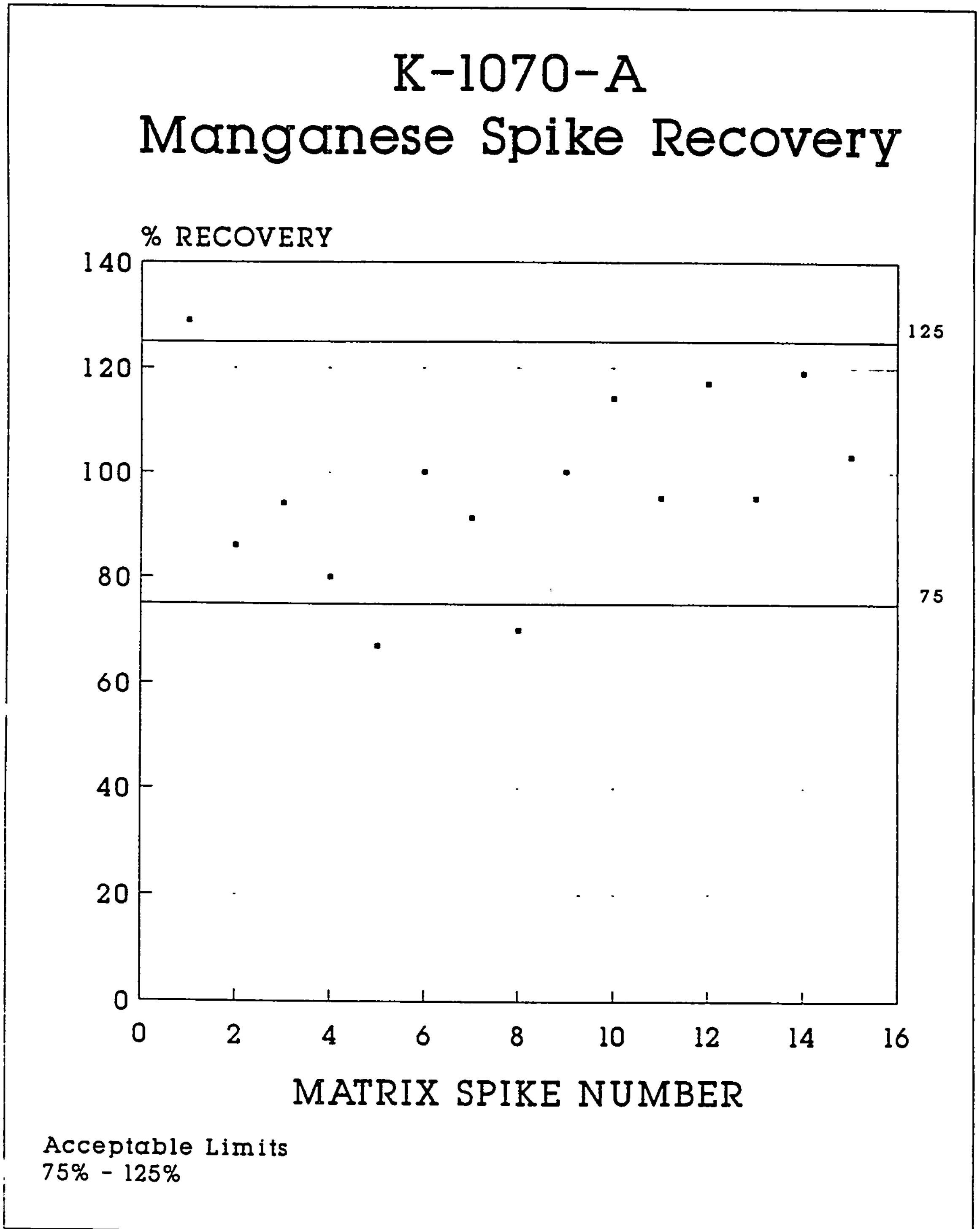


Fig. 18. Manganese matrix spike recovery.

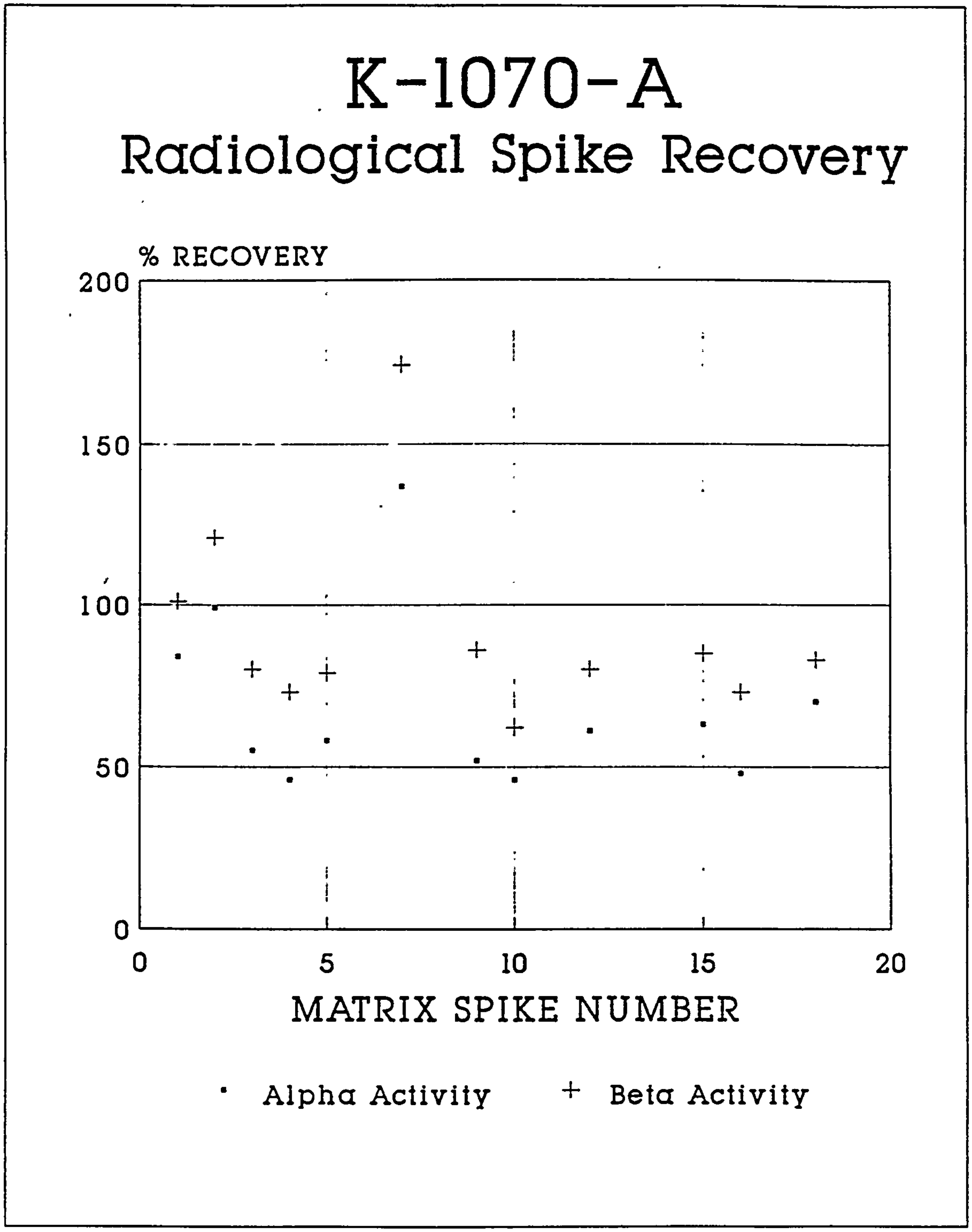


Fig. 19. Gross alpha and gross beta radiation matrix spike recovery.

4.6.2 Organic Surrogate Spike Recoveries (Soil)

The VO and semivolatile surrogate recoveries for the soils analyzed are summarized in Table 8. Despite the 21 occurrences of surrogates outside CLP limits, only three samples (BH007ASO08, BH005ASO32, and BH020ASO44) would have required re-extraction and reanalysis following strict CLP protocol. These samples were not rerun due to insufficient sample quantity.

4.6.3 Organic Matrix Spike Recoveries (Soil)

Six VO matrix spikes and matrix spike duplicates were analyzed as part of the K-1070-A Contaminated Burial Ground investigation. For an undetermined reason, the results for one matrix spike and one matrix spike duplicate were not reported by the laboratory. The results obtained for the remaining five sets are summarized in Table 9. Only one of the samples (BH023ASO08) showed matrix spike recoveries outside CLP limits. All of the low values in Table 8 came from this sample. Because the matrix spike and matrix spike duplicate results were in such close agreement, it is likely that the low matrix spike recoveries are due to some type of matrix effect. There were no matrix spikes performed on any of the soil samples submitted for semivolatile analysis.

4.6.4 Organic Surrogate Spike Recoveries (Water)

Table 10 summarizes the VO and semivolatile surrogate recoveries for the equipment rinsates and field blanks. The VO surrogate recoveries are all within the CLP guidelines, and therefore no problems are anticipated with the VO recoveries from either the equipment rinsates or the field blanks. Very few of the semivolatile surrogate spike components fell outside the CLP limits. Two samples (BH004SE52 and BH004SB52) accounted for 8 of the total (13) surrogate spike components outside CLP limits. Comparison of the recoveries for all spike components from these two samples with the average of the rest indicates that, in all likelihood, too much spike solution was added to these two samples.

4.6.5 Organic Matrix Spike Recoveries (Water)

There were no matrix spike or matrix spike duplicate samples prepared for any water samples submitted for organic analysis as part of the K-1070-A Contaminated Burial Ground investigation.

Table 8. Surrogate spike recovery summary for organics in soil

Surrogate	Outside CLP limits[a]	At CLP limits[a]	CLP limits (μg/kg)
Volatile Organics			
Bromodichlorobenzene	0/61	0/61	74–121
1,2-Dichloroethane-d4	0/61	0/61	70–121
Toluene-d8	0/61	0/61	81–117
Semivolatile Organics			
2,4,6-Tribromophenol	5/24	3/24	19–122
2-Fluorobiphenyl	5/24	1/24	30–115
2-Fluorophenol	3/24	3/24	25–121
Nitrobenzene-d5	0/24	3/24	23–120
Phenol-d6	8/24	1/24	24–113
Terphenyl-d14	0/24	0/24	18–137

[a]Number of samples per recovery/total number of samples.

Table 9. K-1070-A soil organic matrix spike (MS)/matrix spike duplicate (MSD) summary (μg/kg)

Compound	MS recovery (max/min)	MS av recovery (max/min)	MSD recovery (max/min)	MSD av recovery (max/min)	CLP limits
1,1-Dichloroethane	110/18	82	107/20	77	59–172
Benzene	130/34	96	120/35	92	66–142
Chlorobenzene	127/55	103	130/58	100	60–133
Toluene	123/37	94	120/35	91	59–139
Trichloroethene	130/33	94	127/36	90	62–137

Table 10. K-1070-A equipment rinsate/field blank organic surrogate recoveries

Compound	Recovery (max/min) (μg/kg)	Average recovery (μg/kg)	Samples Outside CLP limits[a]	CLP limits (μg/kg)
	Volatile Organics			
Toluene-d8	104/90	97	0/10	88–110
Bromofluorobenzene	115/92	103	0/10	86–115
1,2-Dichloroethane-d4	114/100	104	0/10	76–114
	Semivolatile Organics			
Nitrobenzene-d5	132/42	80	2/32	35–114
2-Fluorobiphenyl	120/46	85	2/32	43–116
Terphenyl-d14	179/46	114	6/32	33–114
Phenol-d6	77/15	43	0/32	10–94
2-Fluorophenol	133/22	67	3/32	21–100
2,4,6-Tribromophenol	113/25	73	0/32	10–123

[a]Number of samples outside limit/number of samples taken.

4.7 SUMMARY OF RESULTS

4.7.1 Inorganic

All the metals analyses (including mercury) were performed within recognized holding times, and matrix spike data were within acceptable limits. Only three metals were found in the equipment rinsates at levels significant enough to cause concern over sample contamination. These metals were copper, zinc, and arsenic. The presence of copper and zinc in equipment rinsates are not seen as data limitations. Arsenic, on the other hand, would be of concern in the evaluation of the arsenic results. It is unclear whether there is a correlation between the results obtained from the equipment rinsates and those obtained from the samples. The arsenic data should be considered advisory. All other metal data are considered usable.

4.7.2 Radiochemical

All gross alpha and gross beta radiochemical results obtained from boreholes cut prior to February 1, 1989 (BH018A, BH012A, BH024A, BH013A, BH021A, and BH011A), must be considered advisory. The reason for the advisory rating is the elevated gross alpha and beta levels found in the equipment rinsates. Although the rinsates are relatively low compared to the soil data, they are elevated enough to cause a real concern about the possibility of cross-contamination between samples. Because field blanks were only submitted toward the end of the investigation, it is impossible to determine if the water used for cleaning was contaminated. Since this is unlikely, it must be assumed that the elevated levels are the result of inadequate equipment decontamination. The remaining radiochemical data are considered satisfactory.

4.7.3 Volatile Organics

All soil sample holding times for VOs were met. Two equipment rinsate samples were analyzed outside their holding times. This is not seen as a significant data limitation. Both the equipment rinsates and the field blanks had similar contamination (acetone, bromodichloromethane, and chloroform). The observed contamination was expected due to the nature of the decontamination solution. Again, there are no apparent data limitations presented by the contamination. If, after careful data analysis, any of the contaminants are determined to be contaminants of concern, their detection limits will need to be adjusted according to guidelines contained in *Laboratory Data Validation-Functional Guidelines for Evaluating Organics Analyses*.[18] The data would then need to be reevaluated considering the revised detection limits. There were no surrogate recovery problems for either the soil or the water samples. Only one soil sample (BH023ASO08) showed VO matrix spike recovery problems (per CLP protocol). Because both the matrix spike and the matrix spike duplicate showed similar recoveries for this sample, it is assumed to be a matrix effect. All recoveries were >10%, and thus no data limitations exist. Because of the limited number of equipment rinsate/field blank samples submitted for VO analysis there were no matrix spikes or matrix spike duplicates prepared.

4.7.4 Semivolatile Organics

All soil and water samples designated to be analyzed for semivolatile organics were analyzed within recognized holding times. One equipment rinsate (BH014ASE20) was contaminated with low levels of polycyclic aromatic hydrocarbons. This same sample also exhibited extraordinarily high phthalate contamination. Other than this sample, the field blanks and equipment rinsates showed the typical low level contamination associated with this analysis, and this contamination is not expected to represent a data limitation. There were 21 individual soil surrogates found outside CLP requirements. Closer examination reveals only three samples (BH007ASO08, BH005ASO32, and BH020ASO44) that would have required re-extraction under CLP protocol. These samples were not re-extracted, however, and thus it is impossible to determine if the low recovery was due to a matrix effect. All surrogate recoveries were found to be >10% and as such do not represent a data limitation. There were 13 aqueous surrogates outside CLP limits; 8 came from 2 samples, which apparently had too much spike added initially. Because the semivolatile analysis was performed solely for the detection of gross organic contamination and the surrogate recoveries were all >10%, the few instances of surrogate recoveries outside CLP limits do not represent a data limitation. Because of the limited number of soil and water samples submitted for semivolatile analyses, no matrix spike or matrix spike duplicate samples were prepared.

5. STATISTICAL EVALUATION OF DATA

The purpose of this evaluation is to identify possible contaminants in the soil that may have migrated from the graves, trenches, and auger holes that make up the K-1070-A Burial Ground. One way this will be achieved is by a statistical test comparing upgradient (background) and downgradient (site) soil sample results for metals and gross radiation measurements. Originally, a statistical analysis was to have been performed on the data derived from the organic analyses of the samples. However, because only a few of samples had detectable quantities of organics, those data are only presented in table form and are not statistically analyzed. Another purpose of this evaluation is to ascertain any spatial distribution of contaminants around the grave sites, particularly downgradient.

The statistical analysis of the K-1070-A soil data is based on the analytical data reported in Appendix B of *Site Characterization Summary for K-1070-A Contaminated Burial Ground*[9] and three-dimensional spatial plots that are included in Appendix C of this report. An analysis of variance approach to the data was attempted, but because of the large number of factors involved (sampling locations, sampling depths, etc.), the model exceeded computer capacity. An approximate t-test was devised to test differences between average background concentrations and average site concentrations. The test and its results are presented in Sect. 5.2.2. An analysis of the three-dimensional spatial plots of certain contaminants is presented in Sect. 5.2.4, and an analysis of the top 4 ft of soil is included in Sect. 5.2.3.

Not all of the statistical techniques discussed in the Data Management Procedures of Chap. 9 of the site-specific RFI Plan[5] were deemed appropriate or necessary for the K-1070-A Burial Ground at this time. For instance, Cohen's statistical method to estimate a mean and standard deviation from censored data could not be used on the nondetected values because the percentage of detected values was too small, and multiple detection limits were present in some cases. (Nondetects are sample results whose true value is less than the sensitivity of the analytical procedure and instrument used in the analysis.) Any time nondetects were encountered, the detection limit was used in the necessary calculations.

5.1 PRELIMINARY CONSIDERATIONS

5.1.1 Statistical Data Quality Review

Prior to any statistical analysis, the data were reviewed in accordance with the *ORGDP Remedial Action Program Data Management Plan,* (K/HS-232).[19] The data were examined for missing, invalid, and/or inappropriate measurements, for statistical outliers, analytical laboratory qualifiers, appropriate replicate measurements, and consistency of units of measurement. Explanations and corrections to the data were coordinated through the RAP data base manager, field operations manager, and analytical laboratory personnel. Documentation of any changes made to the data base is maintained by the RAP data base manager.

5.1.2 Data Reduction

Also before any statistical analysis was done, the raw soil data were reduced to one result per analyte, borehole, and sample depth. In some samples, organic compounds whose exact composition could not be identified were detected. These were designated by the laboratory as TICs. Some samples contained more than one of these TICs. In this situation, the total concentration of TICs for a sample was summed before any statistical analysis was conducted. The concentrations from field replicate samples for the same analyte, borehole, and sample depth were averaged to produce one result.

5.1.3 Analytical Qualifiers

Symbols used to denote qualifications to the data presented below are as follows. There are two qualifiers that affected data reduction, the "J" and the "E." The "J" qualifier denotes a real value that is below the contract-required reporting limit for CLP protocol. The "E" qualifier denotes a value that exceeds the calibration range of the instrument and hence is also an estimated value. In addition, the "B" qualifier identifies sample results whose associated laboratory blanks had detectable levels of the given analyte. The "<" qualifier indicates results below detection limits.

Other qualifiers that were present in the data, but which did not affect reduction, are the "A" and the "P." The qualifier "A" is a laboratory artifact and provides no additional information concerning the quality of the sample result, and the "P" qualifier is associated with the TICs, so the sample result already has a "J" qualifier. Therefore, the "A" and "P" qualifiers will not be used in the following rule (Sect. 5.1.4) for combining analytical qualifiers on averaged or summed results.

5.1.4 Multiple Qualifiers

If any of the qualifiers "E," "<," "B," "BE," "J," or "JB" are attached to any of the sample results which are summed or averaged into one result, the resulting qualifier will be the union of any combination of these qualifiers. The individual qualifiers will simply be appended to each other. For example, a "<JB 50" average result in a table reflects that at least one result used to calculate this average had a "<" qualifier associated with it, at least one other result had a "J" qualifier, and a third result had a "B" qualifier. Similarly, when more than one sample is detected as a maximum or minimum result, all qualifiers applicable to any of the samples detected at that level will be indicated.

5.1.5 Summary Statistics

Summary statistics are calculated using one result per analysis type, analyte, borehole, and depth. Some of these results are the two-level averages over replicates described above (Sect. 5.1.2) along with their combined analytical qualifiers. The following rules are used to calculate these summary statistics.

Maximum Result: The maximum result is the greatest level of detection. If there are no detects, the maximum is the greatest detection limit. The maximum result will be footnoted if there are any nondetects with a detection limit larger than the maximum detected result.

Minimum Result: If there is at least one nondetect, the smallest of the detection limits is used as the minimum result. If all results are detected, the minimum of these results is used. The minimum result will be footnoted if there are any detected results which are less than the minimum detection limit.

Average Result: The average result is an arithmetic average of detected values and detection limits regardless of the associated qualifiers for the individual results. This provides a conservative estimate for the average concentration since the detection limits are used for any nondetected results.

Table 11 provides examples of how qualifiers for individual sample results are indicated in maximum, minimum, and average statistics of subsequent data presentation tables.

Table 11. Examples of combined qualifiers for maximum, minimum, and average statistics

Individual sample results	Maximum result	Minimum result	Average result
B 30, J 35, < 40, 45, JB 50, < 58	JB 50[a]	< 40[b]	<JB 43
B 30, J 35, < 40, 45, JB 50	JB 50	< 40[b]	<JB 40
30, 32, 45, B 50, < 58	B 50[a]	< 58[b]	<B 43
< 30, 35, BE 45, 50	50	< 30	<BE 40
< 30, 30, J 40, B 40	JB 40	< 30	<JB 35

[a]Includes at least one nondetect with a detection limit greater than the maximum detected result.
[b]Includes at least one detected result less than the minimum detection limit.

5.2 STATISTICAL EVALUATION

5.2.1 Review of Soil Sampling

A statistical analysis of the K-1070-A Contaminated Burial Ground Phase 1 soil data has been completed. This analysis focused on data from 294 soil samples from 19 sampling locations. At three locations (11, 17 and 23, shown in Fig. 12) two holes were drilled ~10 ft apart to allow an estimate of small-scale spatial variability. At a fourth location (13) two holes were drilled ~18 in. apart. The second of these holes was not called for in the sampling plan (Chap. 8 of the site-specific RFI Plan)[5] but was drilled because the first met refusal at only 12 ft. After the drilling of the second hole at location 13, a generally very shallow depth to bedrock upgradient from the graves and trenches was discovered, and thereafter samples were taken at 4-ft intervals until refusal at each borehole location (rather than attempting to drill additional holes as at location 13). A sample was also taken at the very bottom of each hole. There were 22 pairs of field replicates taken to allow an estimate of the sampling plus analytical variability. The analysis of laboratory duplicate samples called for in the sampling plan (which would have allowed separate estimates of the analytical variability) was not performed. Borehole locations 2, 7, 13, and 19 are upgradient of the graves and trenches;

samples taken from these locations were used to estimate background concentrations of metals.

5.2.2 Comparison of Site and Background Levels

Samples were not taken from the actual grave sites due to the possibility of intolerably high risk to workers' health and safety posed by the levels of contamination believed to exist within the grave sites. As it is therefore impossible to draw direct conclusions as to the contamination of the soil within the grave sites area, a statistical test was performed to determine whether the soil downgradient of the burial ground (the graves, pits, trenches, auger holes, and the soil between them and in their immediate vicinity) is different from the soil upgradient from the burial ground. The hypothesis adapted for this test was that overall average concentrations of particular contaminants of concern downgradient from the burial ground ("site") are less than or equal to those upgradient from the burial ground ("background"). If the data indicate rejection of this hypothesis, contaminant leakage from the burial area can be assumed.

The site (downgradient) area is an irregularly shaped area of soil down to bedrock around the burial ground, not including the burial ground in the center. Since the sample locations are from a regular grid around the grave sites and samples were taken at regular intervals to bedrock, each sample represents a similar shape and volume of soil. Samples were taken every 4 ft to bedrock within the 100-ft × 100-ft grid, insuring good coverage of the area. An individual sample result then represents a 100-ft × 100-ft × 4-ft volume of soil.

The overall summary for background and site levels for each analyte is provided in tabular form in Appendix D. Statistics include the maximum, minimum, and arithmetic average. A statistical result may reflect a single sample result or may reflect the averaging of a hole pair (see Sect. 5.2.1) or a pair of field blanks. Therefore, the number of individual sample results detected is also reported for each analyte. If multiple sample results are thus indicated, those results were averaged prior to statistical analysis.

Initially, the results from the 22 field replicate pairs were averaged. Next, the results from the paired borehole locations were averaged at each sample depth. This yielded one result for each 100-ft × 100-ft sampling location at each sampling depth to bedrock. The site sample results were averaged together ($\bar{Y}_{site}$) as well as the background results ($\bar{Y}_{background}$). These overall averages were compared with one another. To perform the proposed statistical test, the difference in the site and background averages, $L = \bar{Y}_{site} - \bar{Y}_{background}$, is compared in light of the variability that is present in the data. This variability comes from three sources: small-scale spatial variability (the variability that would result from drilling many holes in a small area and analyzing sample results), sampling variability, and analytical variability. Because there were no laboratory duplicates taken or analyzed, it was not possible to separate the analytical variability from the sampling variability. The sum of these two sources (analytical and sampling) of variability can be estimated from the 22 field replicates. The estimate of the small-scale spatial variability essentially comes from the pairs of boreholes that were drilled at locations 11, 13, 17, and 23. These two components of variability are combined to form the variance of L, and then finally the standard deviation of L (the square root of the variance). The test statistic is the ratio of the difference between the site average and the background average to the standard deviation of the difference. Refer to Appendix E for a more detailed description of the statistical hypothesis test.

For the analyses listed, Table 12 provides a listing of the estimate of the difference: L = $\bar{Y}_{site}$ - $\bar{Y}_{background}$, the estimated variance of L, the computed t-statistic, the degrees of freedom for the test, and the significance level of the test, *p*. Values of $p < 0.05$ signify a statistically significant difference between the average site concentration and the average background concentration with 95% confidence.

Table 12. Approximate T-Test, site vs background at K-1070-A

Analysis	L[a]	$S^2(L)$[b]	T-statistic	DF[c]	*p*-value[d]
Antimony[e]	—	—	—	—	—
Arsenic[e]	—	—	—	—	—
Barium	-6.1960 mg/kg	5.43324 mg/kg²	2.6582	39.3	0.99435
Beryllium	0.03216 mg/kg	7.64E-04 mg/kg²	1.16320	37.5	0.12604
Boron	1.97467 mg/kg	0.94154 mg/kg²	2.03505	37.5	0.02448
Cadmium[e]	—	—	—	—	—
Chromium	0.56686 mg/kg	1.52939 mg/kg²	0.45837	22	0.32559
Cobalt	0.61235 mg/kg	1.68775 mg/kg²	0.47135	39.6	0.31999
Lead	12.6780 mg/kg	16.3631 mg/kg²	3.13413	22	2.41E-03
Magnesium[f]	330.085 mg/kg	1237.56 mg/kg²	9.38303	38.7	8.21E-12
Manganese	602.671 mg/kg	11469.0 mg/kg²	5.62753	39.1	8.42E-07
Molybdenum	0.21998 mg/kg	0.02995 mg/kg²	1.27107	36.7	0.10585
Nickel	1.83214 mg/kg	1.23272 mg/kg²	1.65016	36.6	0.05374
Selenium	6.01995 mg/kg	3.52665 mg/kg²	3.20562	37.3	.001382
Silver[e]	—	—	—	—	—
Strontium	-0.4777 mg/kg	0.04978 mg/kg²	-2.1411	36.3	0.98048
Uranium	2.83225 mg/kg	23.9740 mg/kg²	0.57844	22	0.28442
Vanadium	1.55691 mg/kg	7.48383 mg/kg²	0.56912	22	0.28752
Zinc	5.24113 mg/kg	82.3336 mg/kg²	0.57761	22	0.28470
Alpha activity	0.02212 pCi/g	1.04876 pCi/g²	0.02160	22	0.49148
Beta activity	26.9023 pCi/g	352.555 pCi/g²	1.43277	36.2	0.08025
Gamma activity	-0.2286 pCi/g	0.06177 pCi/g²	-0.9199	21	0.81596

[a]L = Difference between site and background averages.
[b]Estimated variance of L.
[c]Degree of freedom.
[d]Signifigance level.
[e]Insufficient results above detection limit to perform t-test.
[f]The result for Sample Number 890122-015 for magnesium, which 15.6 times greater than next largest result, was considered an outlier. Excluding this sample, the values for magnesium are as follows:

Analysis	L	S(L)	T-Statistic	DF	*p*-Value
Magnesium	93.2725	1238.14	2.65076	38.7	5.79E-03

Table 12 shows the results for the statistical hypothesis test comparing upgradient and downgradient areas. Analytes with results which are below detection limits pose problems because their exact quantity is unknown. The more samples that have concentrations below detection limits for an analyte, the greater the impact on the statistical t-test, and that impact cannot be quantified. If the percentage of these samples is not excessive, the test should still be valid. Antimony, arsenic, cadmium and silver were not tested due to insufficient data above detection limits, especially in the background samples. Boron, molybdenum, and selenium were tested, but it should be noted that each had some data less than the detection limit. All other analytes had no data below detection limits.

The hypothesis (that the site average is less than or equal to the background average) is rejected at the 0.05 level for boron, lead, magnesium, manganese, and selenium. The hypotheses for nickel and beta activity is rejected at the 0.10 level. All other tests show no statistical difference between the average site concentrations and average background concentrations. The extremely small *p*-value for magnesium can be explained in part by the fact that one sample result (890122-015) was more than one order of magnitude greater than the other results. A Grubb's Outlier Test was performed on the magnesium data. The result of 39,000 mg/kg (890122-015) yields a Grubb's T statistic of 7.3, showing that result to be a statistical outlier, but as yet there is no physical evidence to exclude it from the data base. When the apparent outlier is omitted for the purpose of this test, the null hypothesis is still rejected but at a lower level of significance.

5.2.3 Summary of the Four-Foot Samples

An evaluation of samples collected from the 4-ft level is summarized in Table 13. Since the site was capped with 4 ft of soil as a remediation measure, the sample results from the 4-ft level are of special interest. Table 13 provides summary statistics on the 4-ft soil data by analyte. The analytes are grouped into the types of analyses conducted, such as metals, mercury, radiochemical, and volatile organics. Within each analysis type the analytes are listed alphabetically. The number of results, the number of results not detected, the smallest and largest detection limits, the smallest and largest detected results, the average result, and the corresponding units are given for each analyte.

Of the 69 analytes analyzed from the surface soil, only 8 had their largest detected result across the site present at the 4-ft depth. These were barium, silicon, silver, strontium, 2-butanone, 4-methyl-2-pentanone, acetone, and methylene chloride. This table shows relatively high concentrations for the metals aluminum, calcium, iron, manganese, and silicon. The only volatile organic which had a high result was acetone, with 37,000 μg/kg. Note that of the analytes mentioned above, barium, manganese, silver, strontium, 2-butanone, and 4-methyl-2-pentanone are included in the list of potential contaminants of concern, and methylene chloride, acetone, and 2-butanone are indicated as laboratory artifacts.

Table 13. Summary of surface soils analyses over the entire K-1070-A Contaminated Burial Ground by analysis type at the 4-ft depth

Analysis Type	Analysis Name	Number of Results	Number Not Detected	Detection Limits		Detected Results		Average Result[a]	Units
				Minimum	Maximum	Minimum[a]	Maximum[a]		
ICP-Metals	Aluminum	23	0			7200	18000	11863	mg/kg
ICP-Metals	Antimony	23	22	< 5	< 5	5.1	5.1	< 5.004	mg/kg
ICP-Metals	Arsenic	23	15	< 5	< 5	5.7	25	< 8.004	mg/kg
ICP-Metals	Barium	23	0			24	210	66.26	mg/kg
ICP-Metals	Beryllium	23	0			0.19	0.9	0.383	mg/kg
ICP-Metals	Boron	23	13	< 0.4	< 0.4	0.92	12	< 2.694	mg/kg
ICP-Metals	Cadmium	23	12	< 0.3	< 0.3	0.34	1.1	< 0.45	mg/kg
ICP-Metals	Calcium	23	0			82	3900	1168	mg/kg
ICP-Metals	Chromium	23	0			4.7	20	13.9	mg/kg
ICP-Metals	Cobalt	23	0			5.1	18	13.26	mg/kg
ICP-Metals	Copper	23	0			3.8	14	8.698	mg/kg
ICP-Metals	Iron	23	0			7700	25000	16761	mg/kg
ICP-Metals	Lead	23	0			11	35	26.39	mg/kg
ICP-Metals	Magnesium	23	0			330	870	572.8	mg/kg
ICP-Metals	Manganese	23	0			510	4200	1914	mg/kg
ICP-Metals	Molybdenum	23	15	< 1	< 1	1.1	2.3	< 1.174	mg/kg
ICP-Metals	Nickel	23	0			3.7	11	7.104	mg/kg
ICP-Metals	Potassium	23	0			180	980	562.6	mg/kg
ICP-Metals	Selenium	23	8	< 5	< 5	7.9	25	< 10.87	mg/kg
ICP-Metals	Silicon	23	0			480	1100	766.1	mg/kg
ICP-Metals	Silver	23	22	< 0.6	< 0.6	0.78	0.78	< 0.608	mg/kg
ICP-Metals	Sodium	23	4	< 2	< 6.5	4.4	80	< 24.51	mg/kg
ICP-Metals	Strontium	23	0			1.7	8.8	4.046	mg/kg
ICP-Metals	Thorium	23	23	< 20	< 20			< 20	mg/kg
ICP-Metals	Uranium 238	23	19	< 3	< 3	3	19	< 3.848	mg/kg
ICP-Metals	Vanadium	23	0			15	46	30.65	mg/kg
ICP-Metals	Zinc	23	0			13	62	36.33	mg/kg
Mercury	Mercury	23	23	< 1	< 1			< 1	mg/kg
Other	Extractable Fluorides	22	21	< 40	< 40	64	64	< 41.09	mg/kg
Other	Fluoride	1	1	< 40	< 40			< 40	mg/kg
Radiation	Alpha Activity	23	0			-0.95	9.35	4.954	pCi/g
Radiation	Beta Activity	23	0			-14.3	127.2	34.81	pCi/g
Radiation	Gamma Activity	23	0			0	4.23	0.184	pCi/g
VOA	1,1,1-Trichloroethane	7	7	< 14	<290			< 60.57	μg/kg
VOA	1,1,2,2-Tetrachloroethane	7	7	< 14	<290			< 60.57	μg/kg
VOA	1,1,2-Trichloroethane	7	7	< 14	<290			< 60.57	μg/kg
VOA	1,1-Dichloroethane	7	7	< 14	<290			< 60.57	μg/kg

Table 13. Summary of surface soils analyses over the entire K-1070-A Contaminated Burial Ground by analysis type at the 4-ft depth (continued)

Analysis Type	Analysis Name	Number of Results	Number Not Detected	Detection Limits Minimum	Detection Limits Maximum	Detected Results Minimum[a]	Detected Results Maximum[a]	Average Result[a]	Units
VOA	1,1-Dichloroethene	7	7	< 14	<290			< 60.57	µg/kg
VOA	1,2-Dichloroethane	7	7	< 14	<290			< 60.57	µg/kg
VOA	1,2-Dichloroethene (total)	7	7	< 14	<290			< 60.57	µg/kg
VOA	1,2-Dichloropropane	7	7	< 14	<290			< 60.57	µg/kg
VOA	2-Butanone	7	2	< 29	< 30	J 27	B 660	<JB 134.3	µg/kg
VOA	2-Hexanone	7	7	< 29	<580			< 121.1	µg/kg
VOA	2-Propanol	1	0			TJ 1000	TJ 1000	TJ 1000	µg/kg
VOA	4-Methyl-2-pentanone	7	6	< 29	<580	J 7	J 7	<J 113.6	µg/kg
VOA	Acetone	7	1	< 30	< 30	B 58	BE 37000	<BE 5417	µg/kg
VOA	Benzene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Bromodichloromethane	7	7	< 14	<290			< 60.57	µg/kg
VOA	Bromoform	7	7	< 14	<290			< 60.57	µg/kg
VOA	Bromomethane	7	7	< 29	<580			< 121.1	µg/kg
VOA	Carbon Disulfide	7	7	< 14	<290			< 60.57	µg/kg
VOA	Carbon Tetrachloride	7	7	< 14	<290			< 60.57	µg/kg
VOA	Chlorobenzene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Chloroethane	7	7	< 29	<580			< 121.1	µg/kg
VOA	Chloroform	7	6	< 14	<290	J 3	J 3	<J 56.71	µg/kg
VOA	Chloromethane	7	7	< 29	<580			< 121.1	µg/kg
VOA	Dibromochloromethane	7	7	< 14	<290			< 60.57	µg/kg
VOA	Ethyl benzene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Hydrocarbon	3	0			TJB 66	TJB 86	TJB 73.33	µg/kg
VOA	Methylene Chloride	7	6	< 14	<290	120	120	< 75.57	µg/kg
VOA	Styrene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Tetrachloroethene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Toluene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Trichloroethene	7	7	< 14	<290			< 60.57	µg/kg
VOA	Vinyl Acetate	7	7	< 29	<580			< 121.1	µg/kg
VOA	Vinyl Chloride	7	7	< 29	<580			< 121.1	µg/kg
VOA	Xylene (total)	7	7	< 14	<290			< 60.57	µg/kg
VOA	cis-1,3-Dichloropropene	7	7	< 14	<290			< 60.57	µg/kg
VOA	trans-1,3-Dichloropropene	7	7	< 14	<290			< 60.57	µg/kg

[a]The qualifier T denotes a tentatively identified compound. See Sect. 5.1.4 for explanation of other qualifiers.

5.2.4 Description of Figures

Figure 20 shows the spatial relationship among the soil borings at the K-1070-A site. The length of the needle depicting each boring is directly related to the maximum depth of the boring. The small diamonds atop the needles show the site soil borings, while the flags represent the background soil borings. In this and all subsequent figures the plots should be viewed as if one were standing to the east of the burial ground looking west. North is to the right and south to the left. A rough outline of the area surrounding the graves, trenches, and auger holes is included as a point of reference.

Figures 21–38 are graphical displays of K-1070-A soil data for those analytes for which the t-test was not performed (antimony, arsenic, cadmium, and silver) and those which were indicated to vary significantly from background by the t-test. In the case of field replicates, the data that are plotted are the averages for the pairs. Each analyte is illustrated by three plots. Each plot represents a 20-ft soil interval. The needles in the plots are arranged from right (being the shallower samples of the group) to left (deeper down the hole). The needles with a diamond on top represent detected results, while needles with a flag on top represent results less than the detection limit. The height of each needle represents the concentration of the given contaminant at the location of the needle at the given depth. The height of the needle in the case of nondetects indicates the detection limit.

Cadmium, lead, and magnesium (Figs. 21–29), as well as a number of other inorganics, show a tendency towards increased concentrations at greater depths. Since the downgradient bore holes are the deepest, it appears that these elevated concentrations could be attributed to the burial ground. However, this could be the result of natural processes in the soil and of the soil type itself. Boron (Figs. 30–32) shows quite a bit of disparity in the results among the different boreholes. Manganese concentrations (Figs. 33–35) are elevated all the way to bedrock in boreholes on the west side of the burial ground (3, 4, 5, 6, and 12). Elevated levels of beta activity (Figs. 36–38) occur in boreholes 11A and 20 at depths from 20 to 40 ft. Additional plots are included in Appendix C.

5.3 CONCLUSIONS

The statistical analysis of the K-1070-A Contaminated Burial Ground soil data was concentrated in three areas: a statistical hypothesis test comparing upgradient and downgradient areas, an evaluation of the 4-ft level samples, and three-dimensional plots of certain analytes.

The statistical hypothesis test performed on metals and gross radiation measurements gave evidence for differences in average upgradient and downgradient concentration levels for beta activity, boron, lead, magnesium, manganese, nickel, and selenium. Upon review of the three-dimensional plots for these analytes, no clear patterns of concentration differences between upgradient and downgradient areas are seen. This lends support to this report's overall conclusion that contamination from the graves, trenches, and auger holes is not migrating laterally to the surrounding soil.

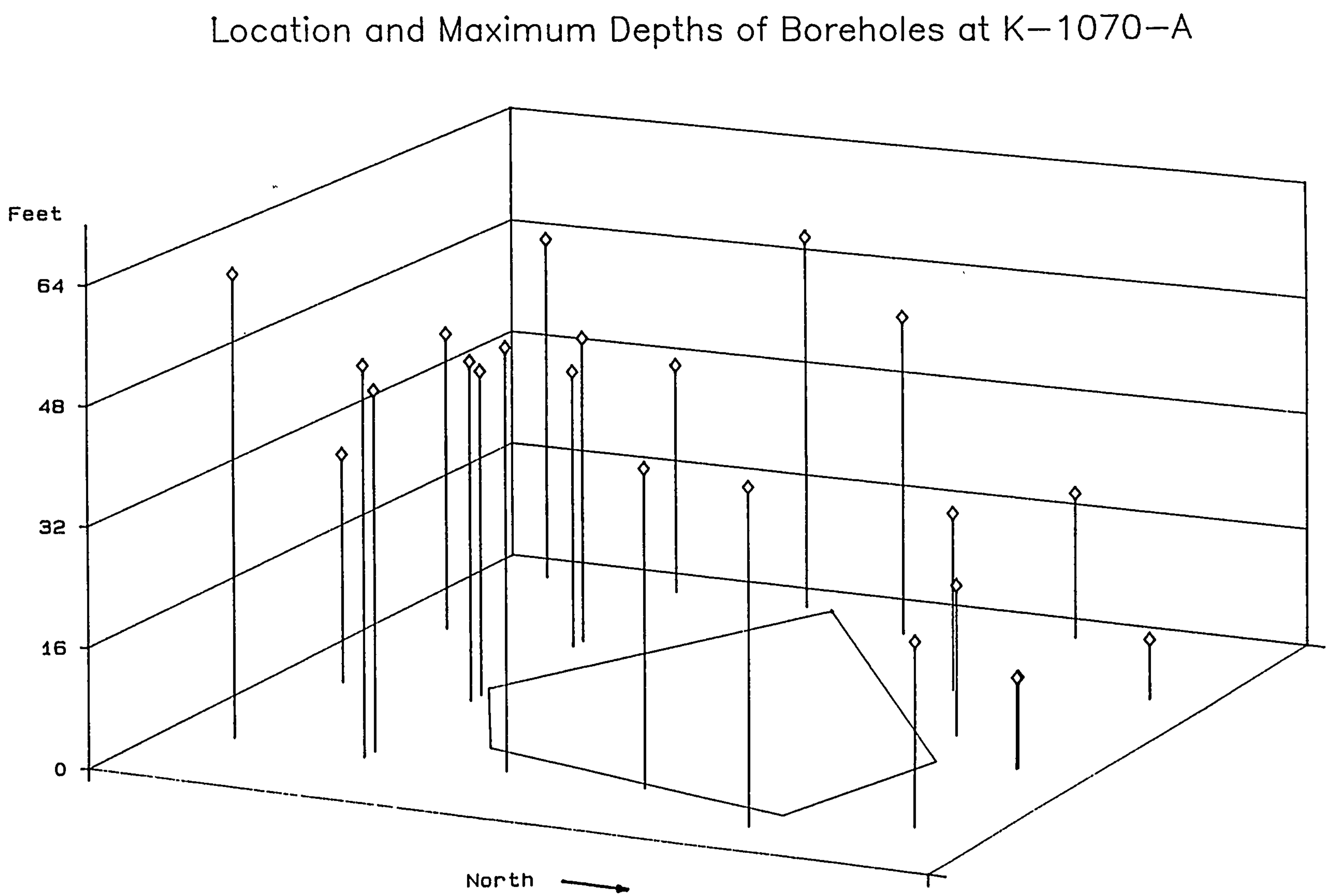
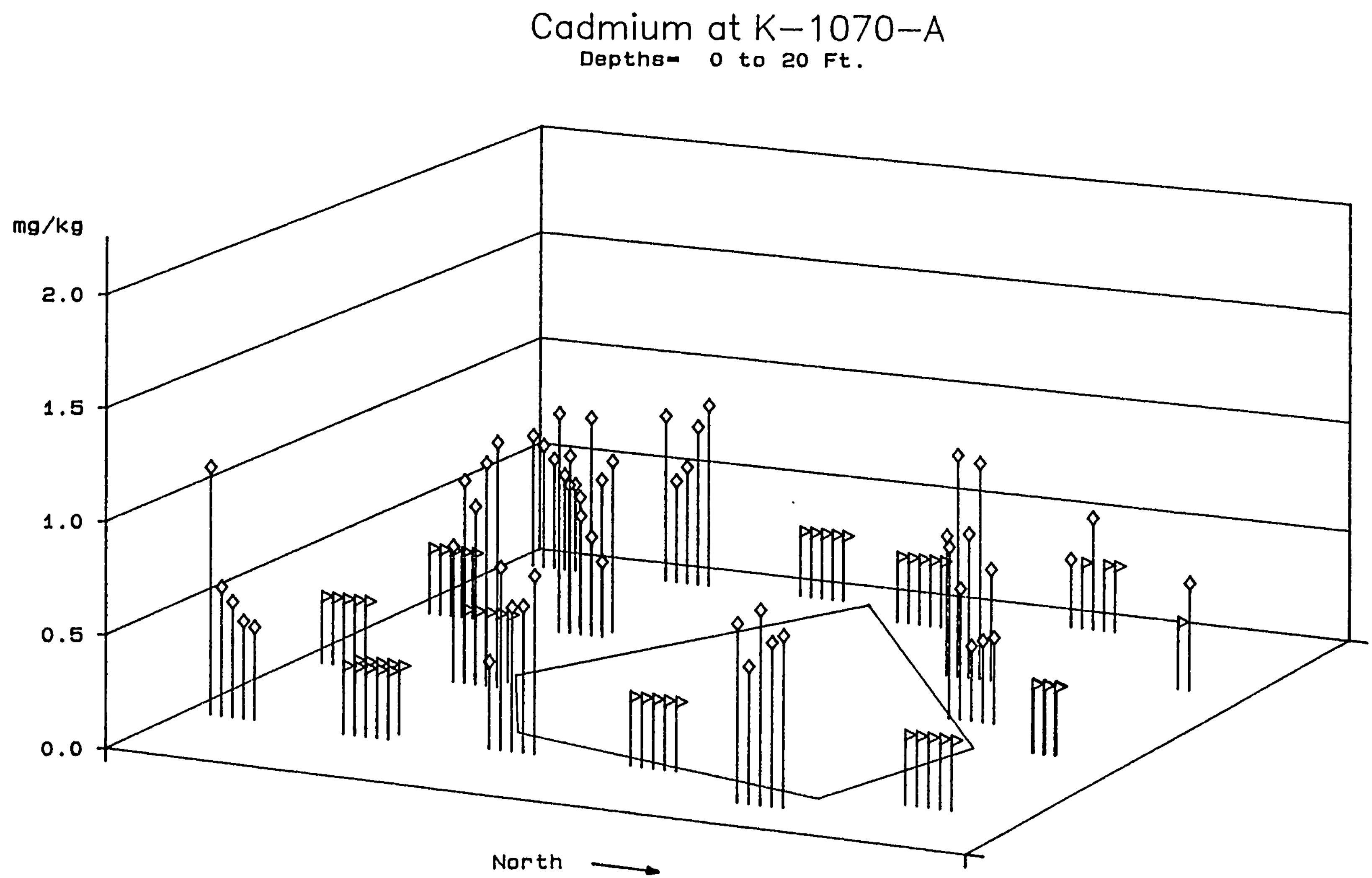


Fig. 20. Location and maximum depths of soil borings at K-1070-A.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 21. Cadmium distribution in 0 to 20 ft samples.

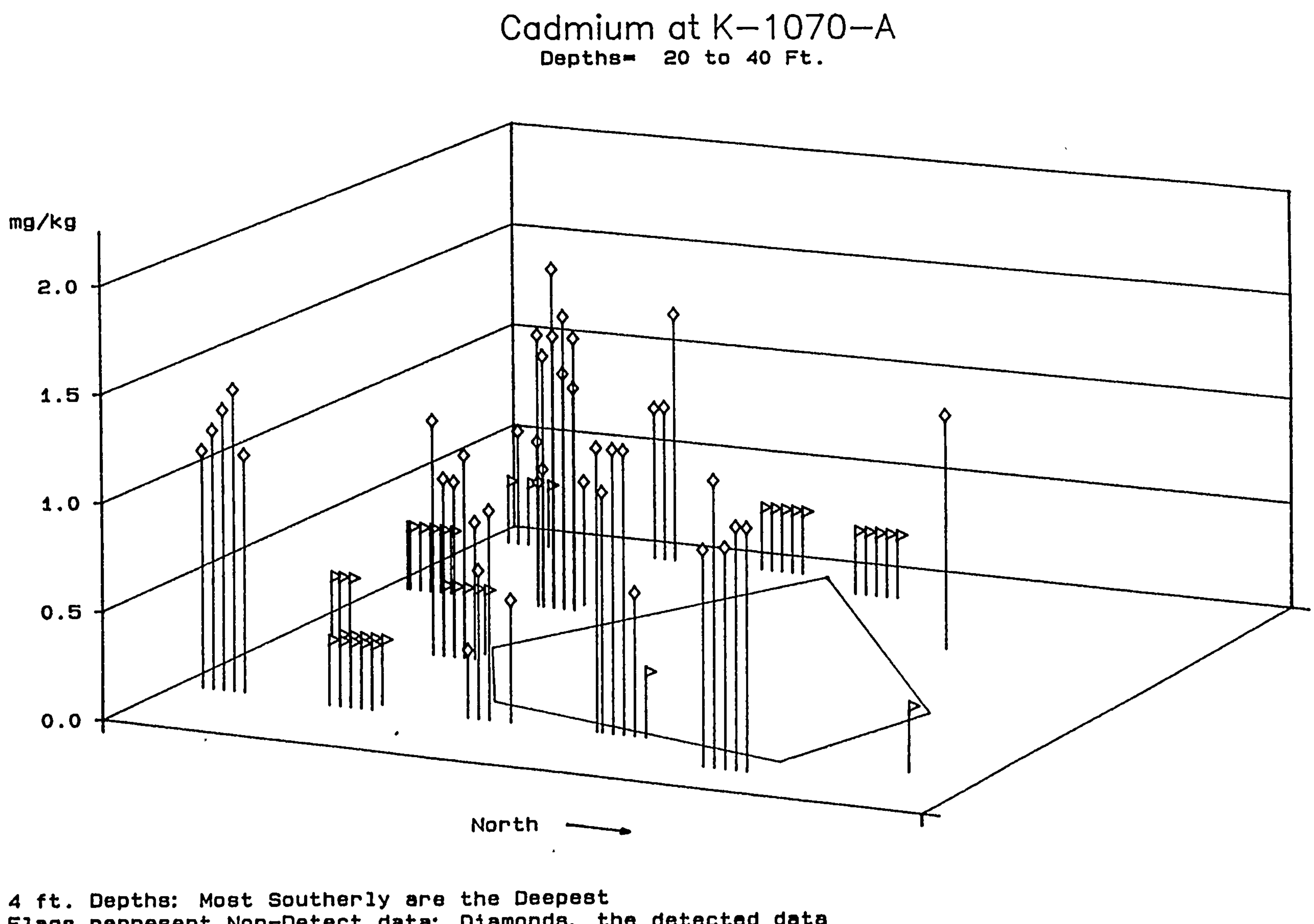


Fig. 22. Cadmium distribution in 20 to 40 ft samples.

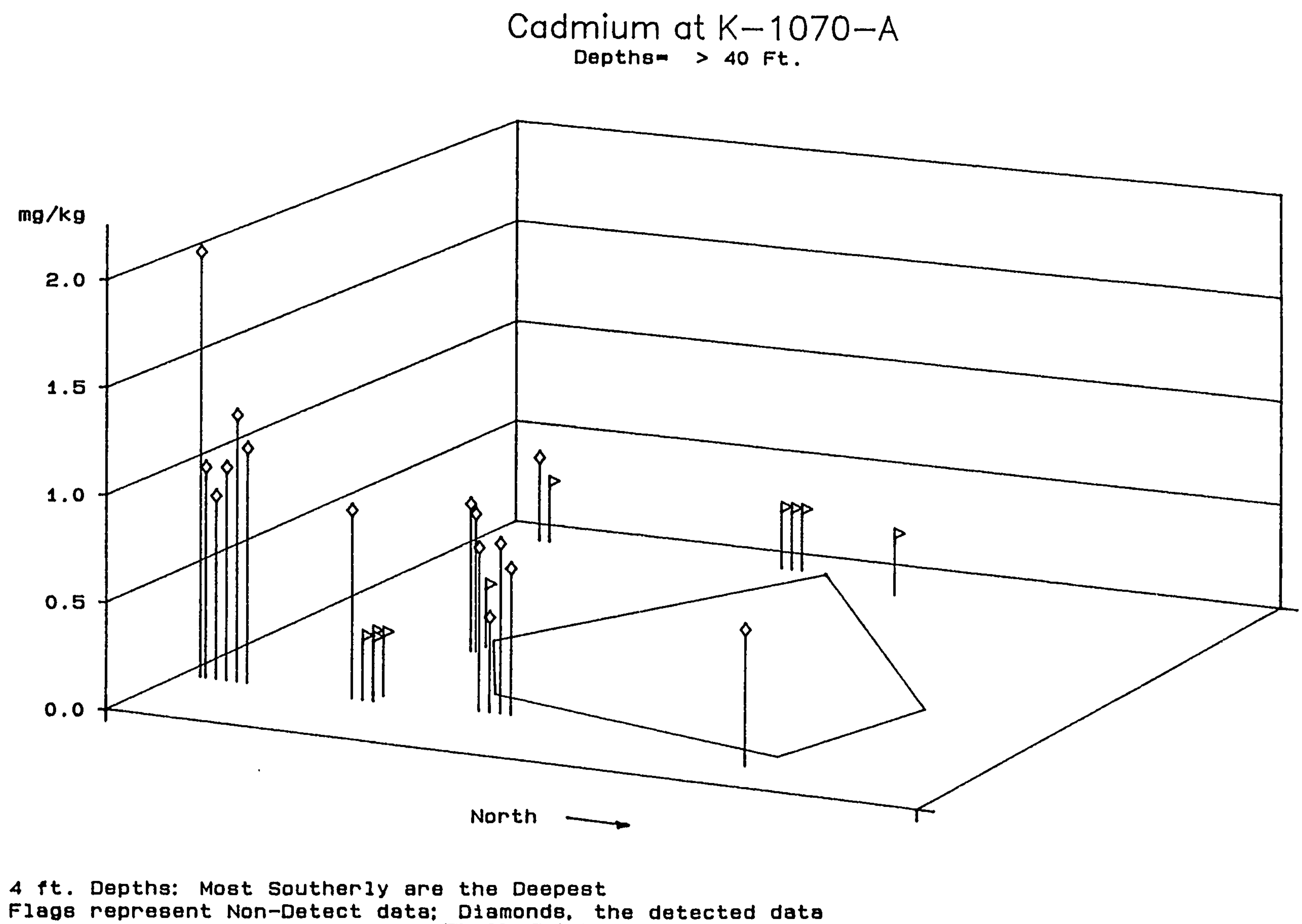


Fig. 23. Cadmium distribution in samples > 40 ft.

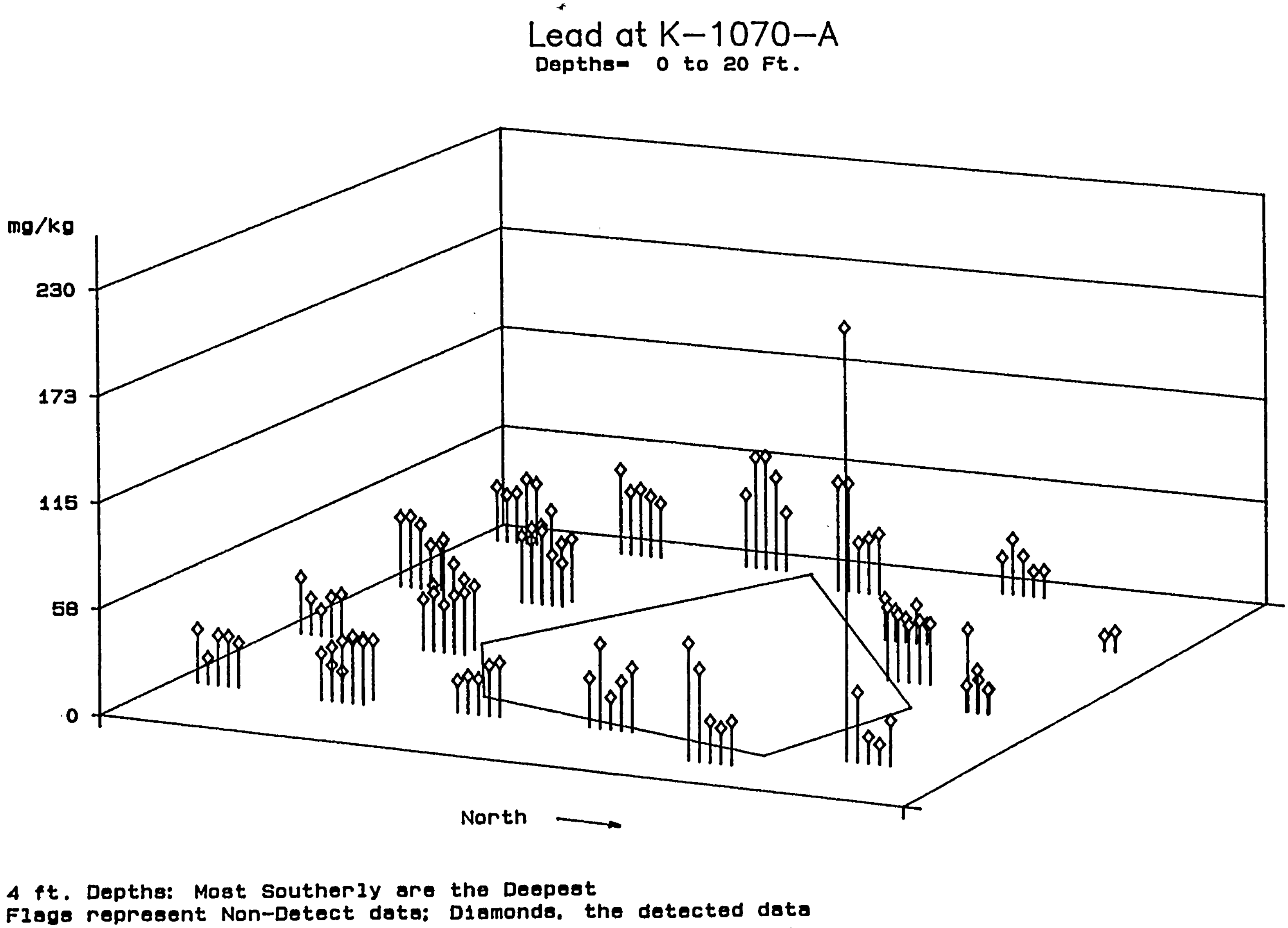
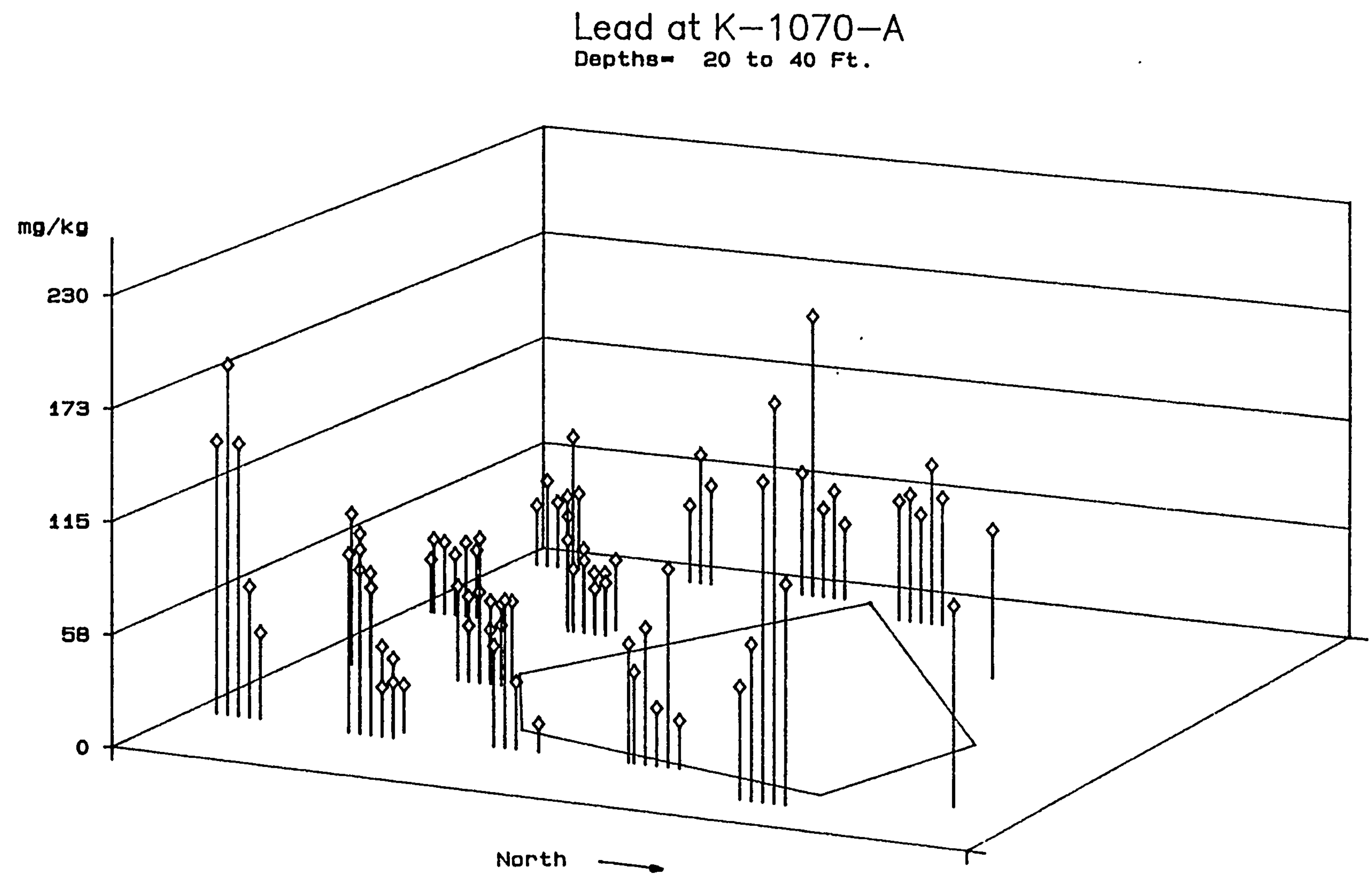
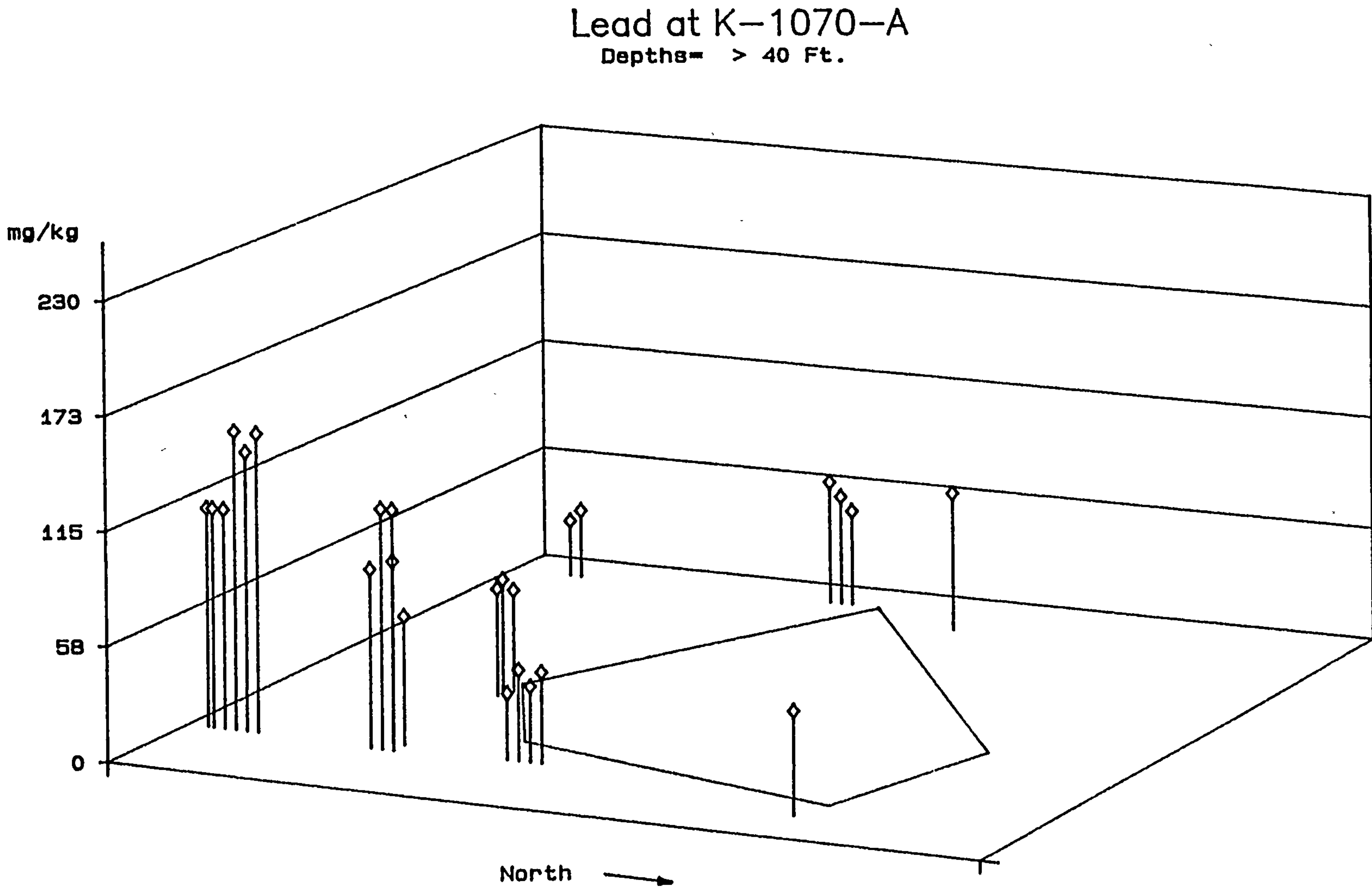


Fig. 24. Lead distribution in 0 to 20 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 25. Lead distribution in 20 to 40 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 26. Lead distribution in samples > 40 ft.

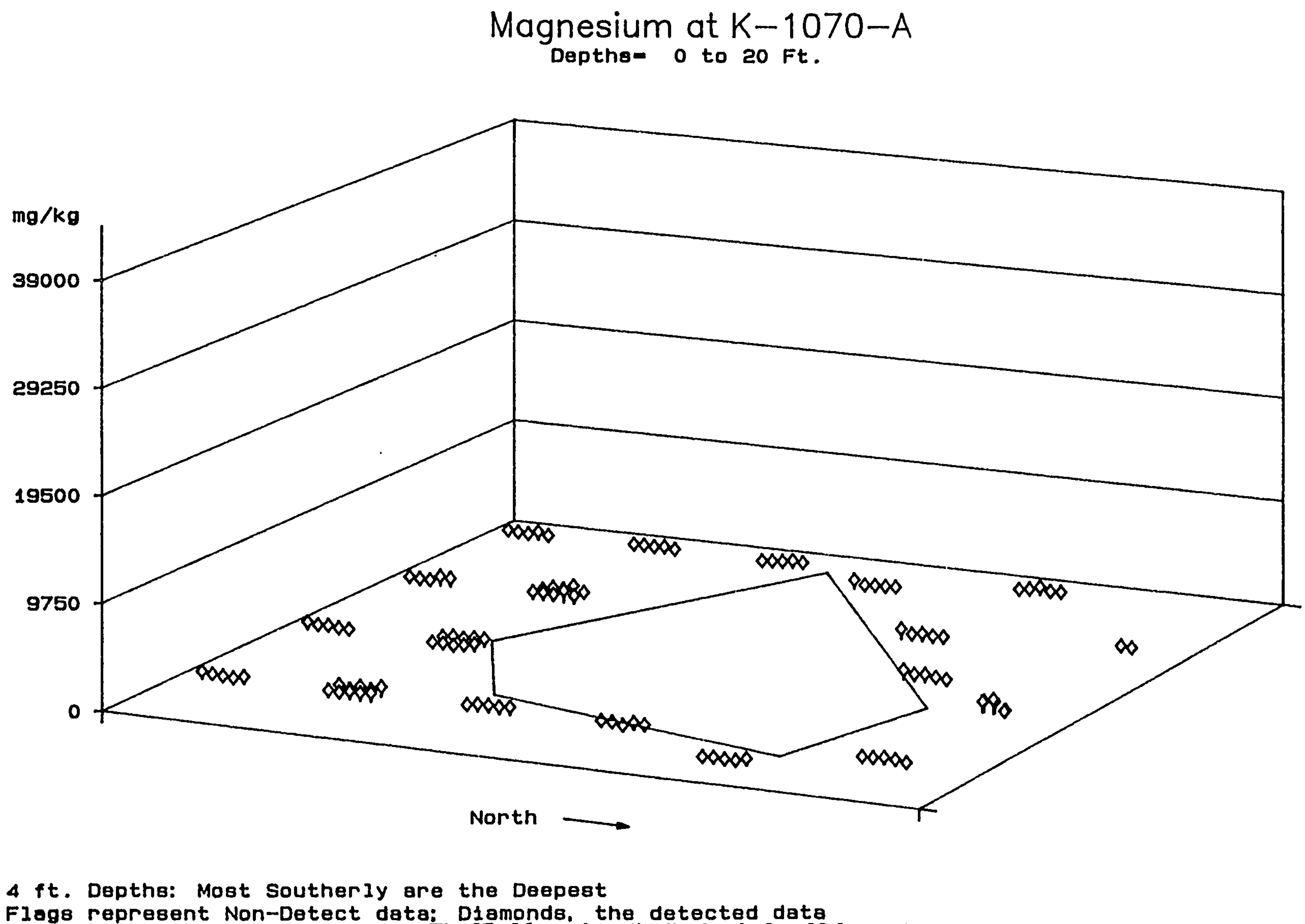
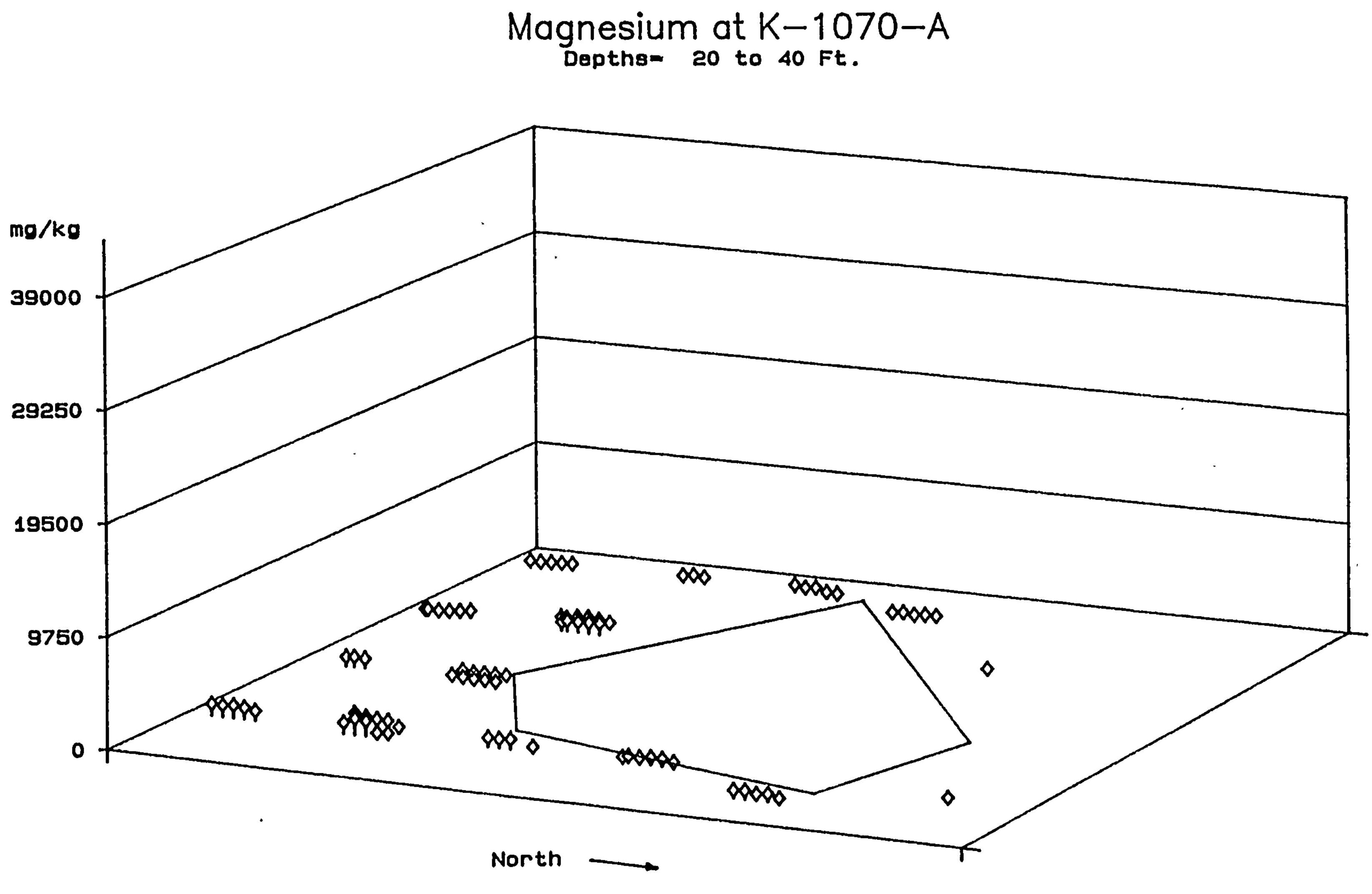
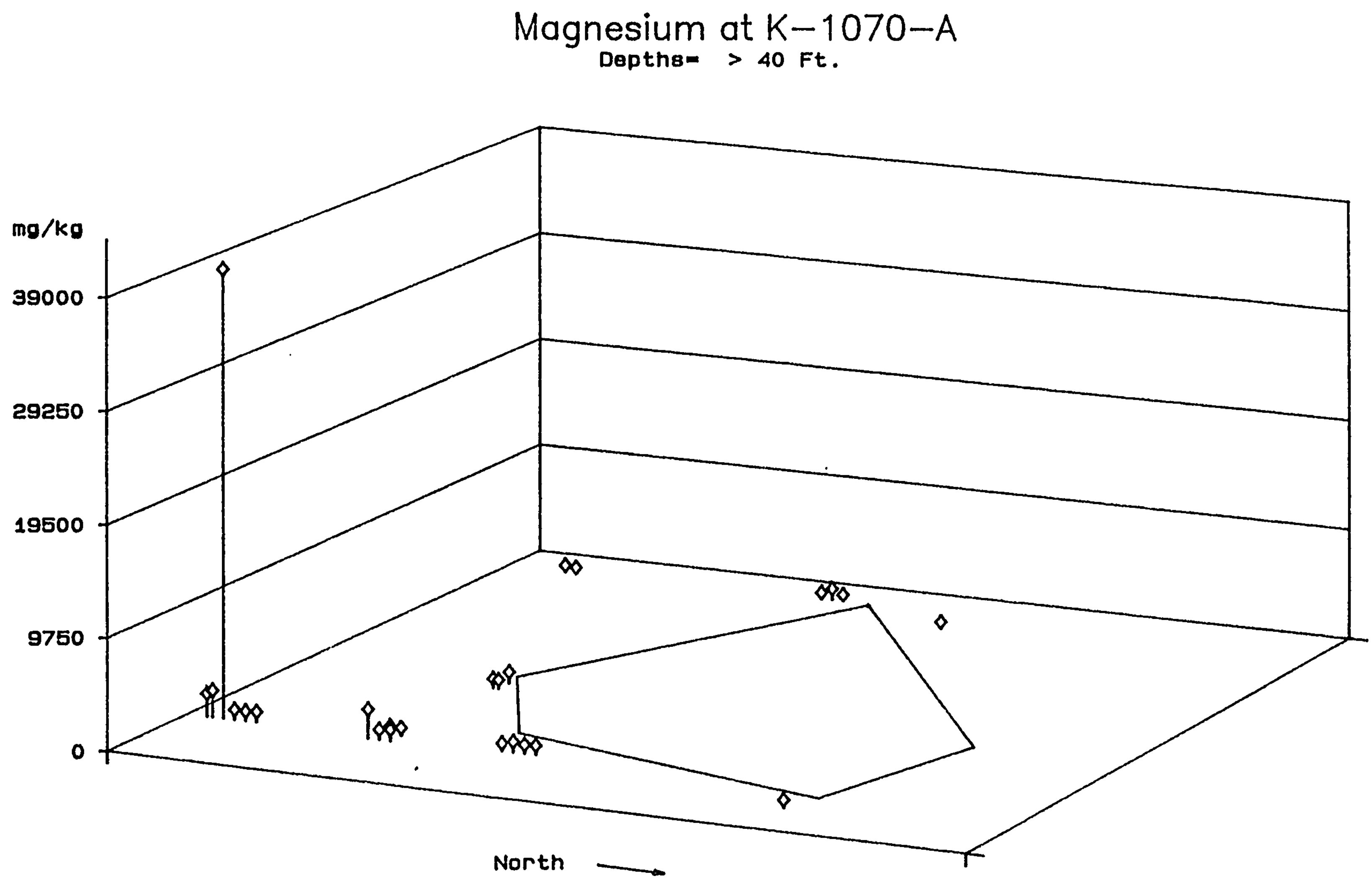


Fig. 27. Magnesium distribution in 0 to 20 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 28. Magnesium distribution in 20 to 40 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 29. Magnesium distribution in samples > 40 ft.

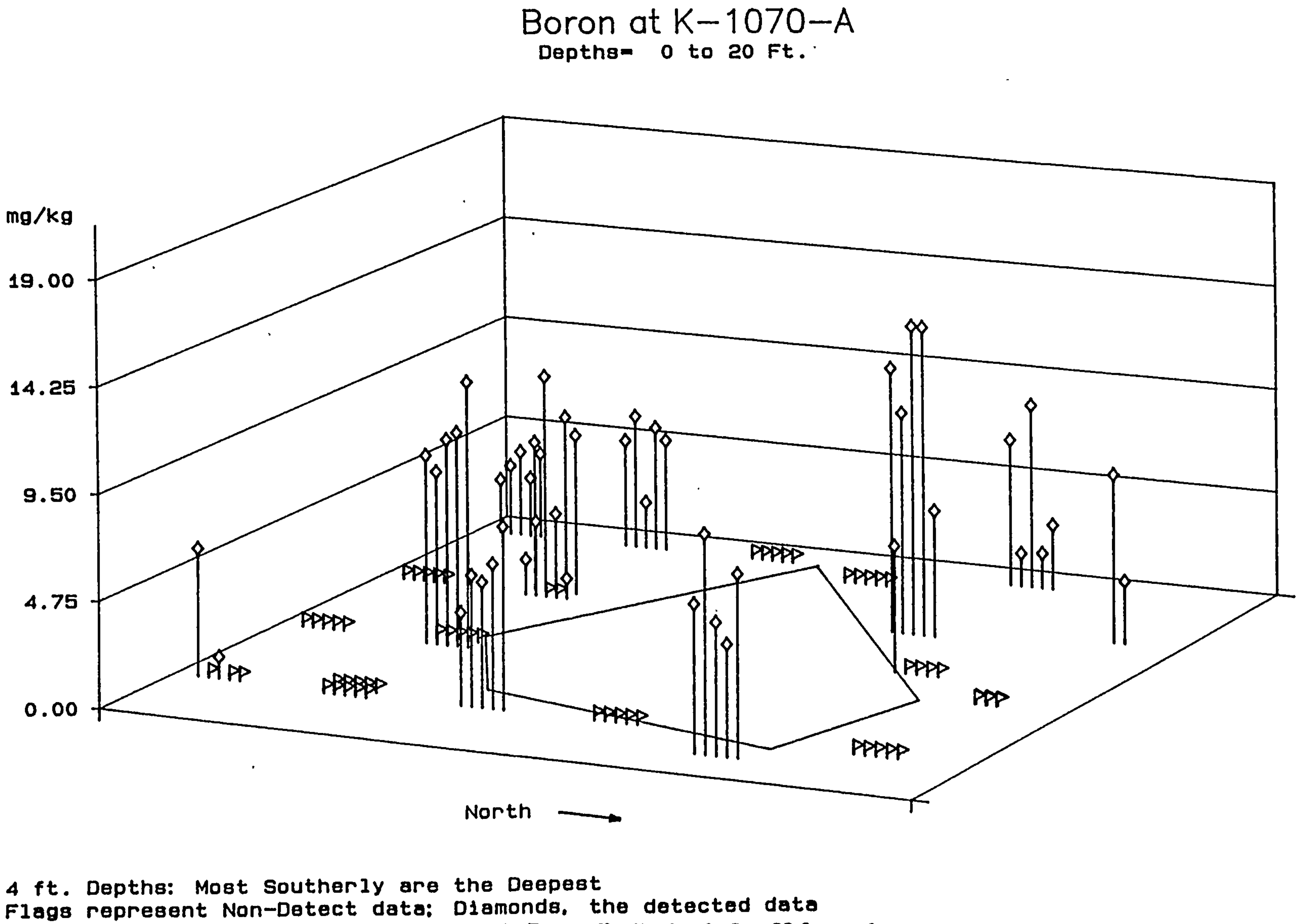


Fig. 30. Boron distribution in 0 to 20 ft samples.

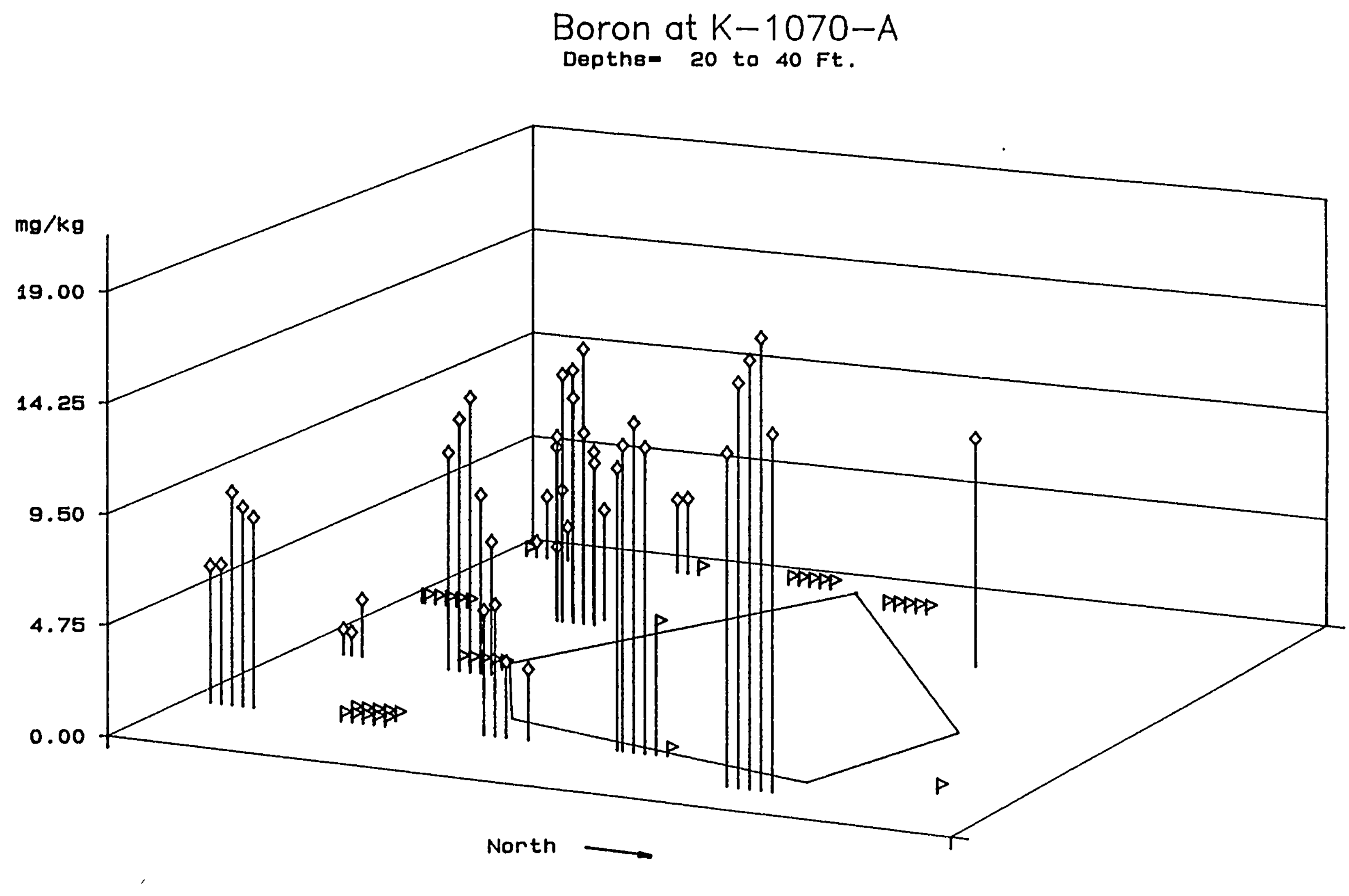
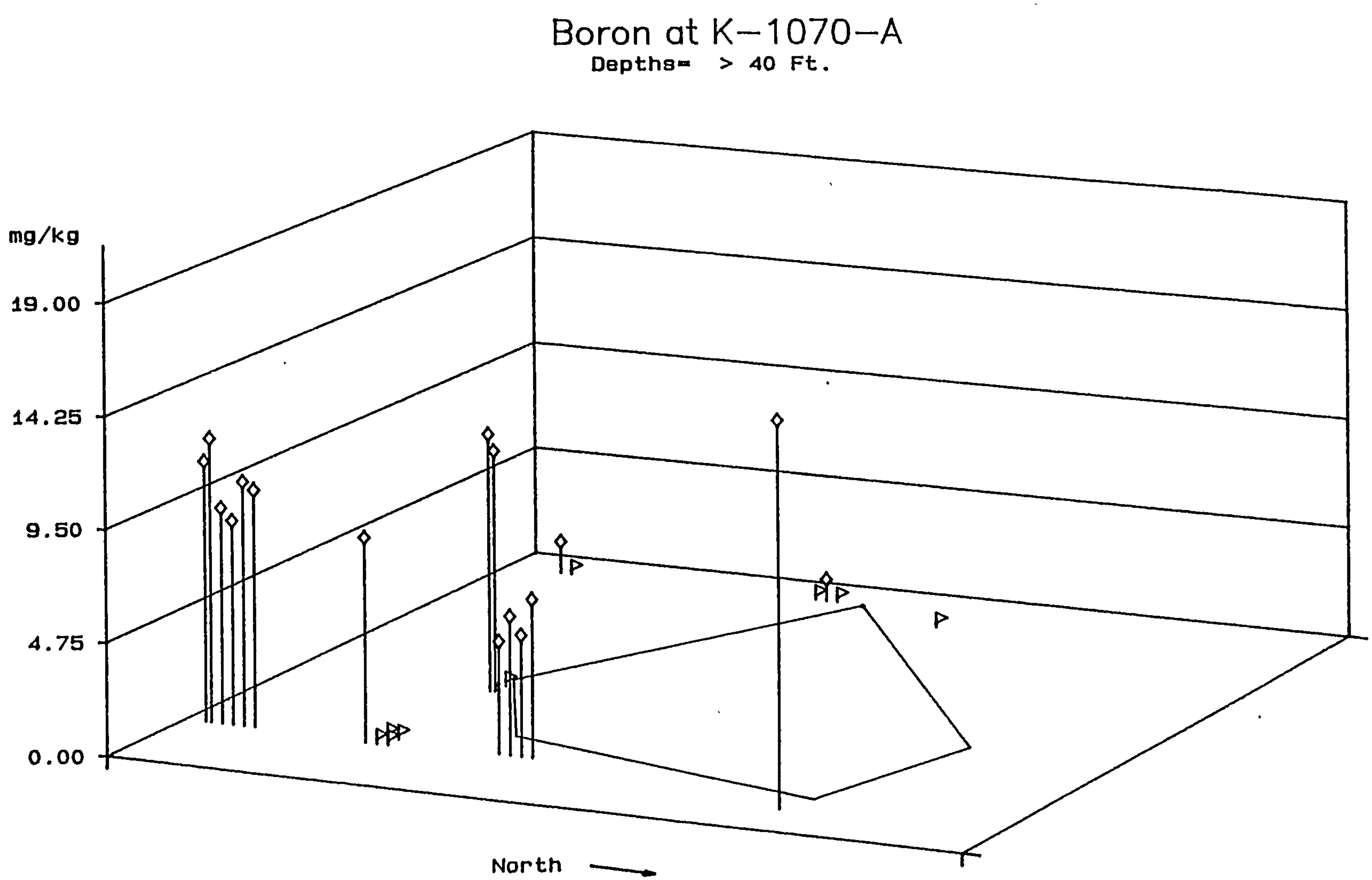
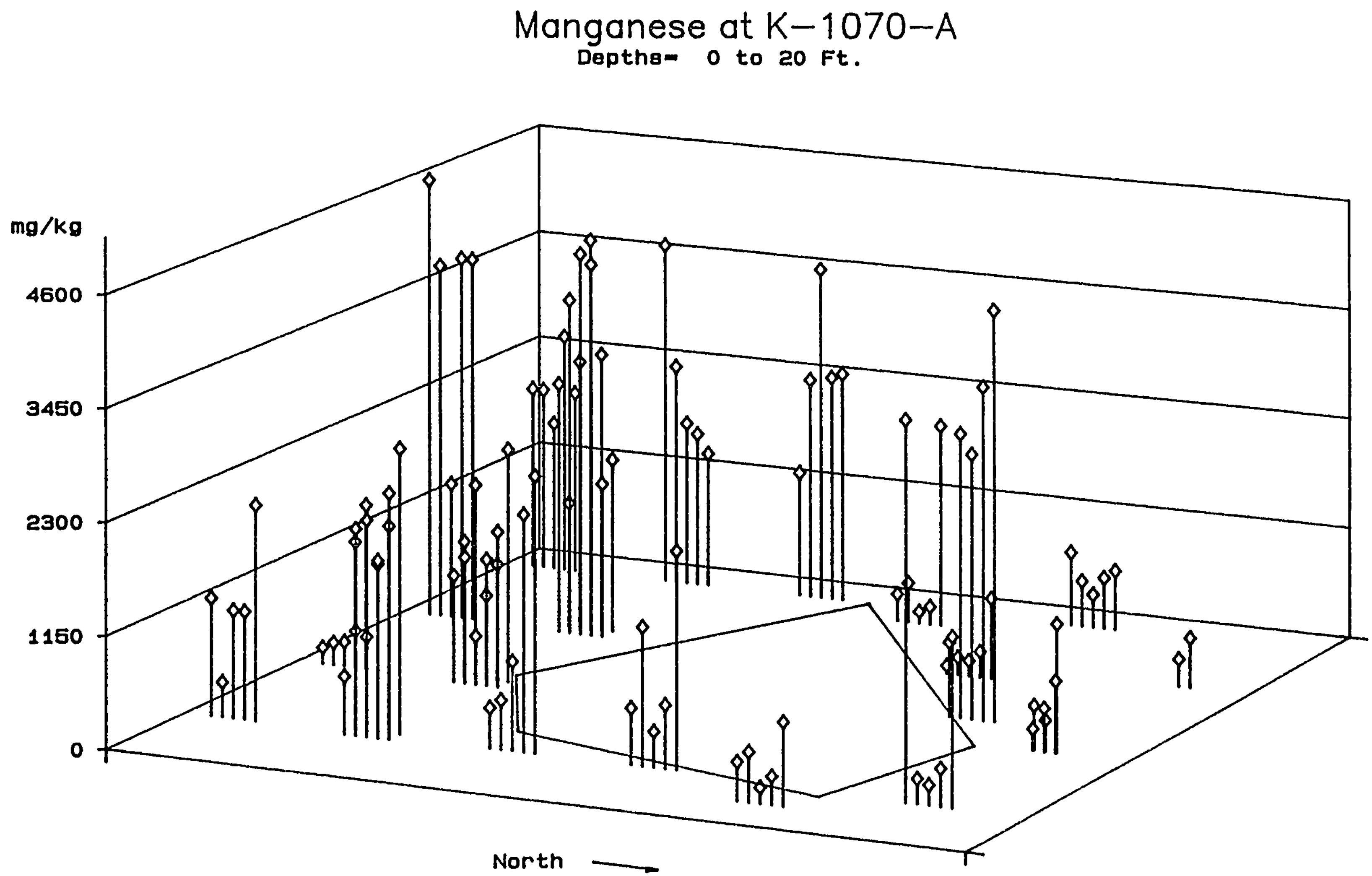


Fig. 31. Boron distribution in 20 to 40 ft samples.



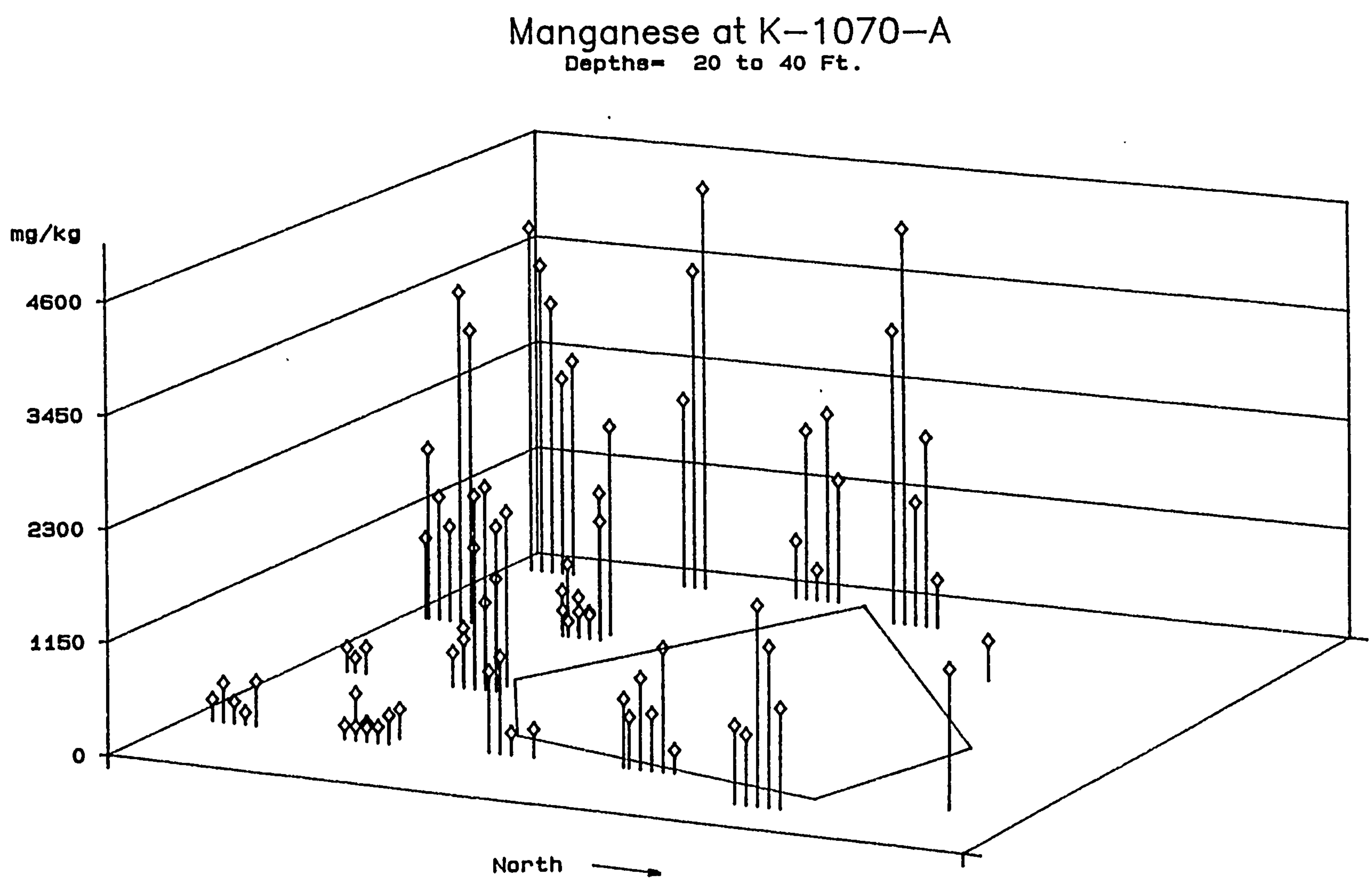
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 32. Boron distribution in samples > 40 ft.



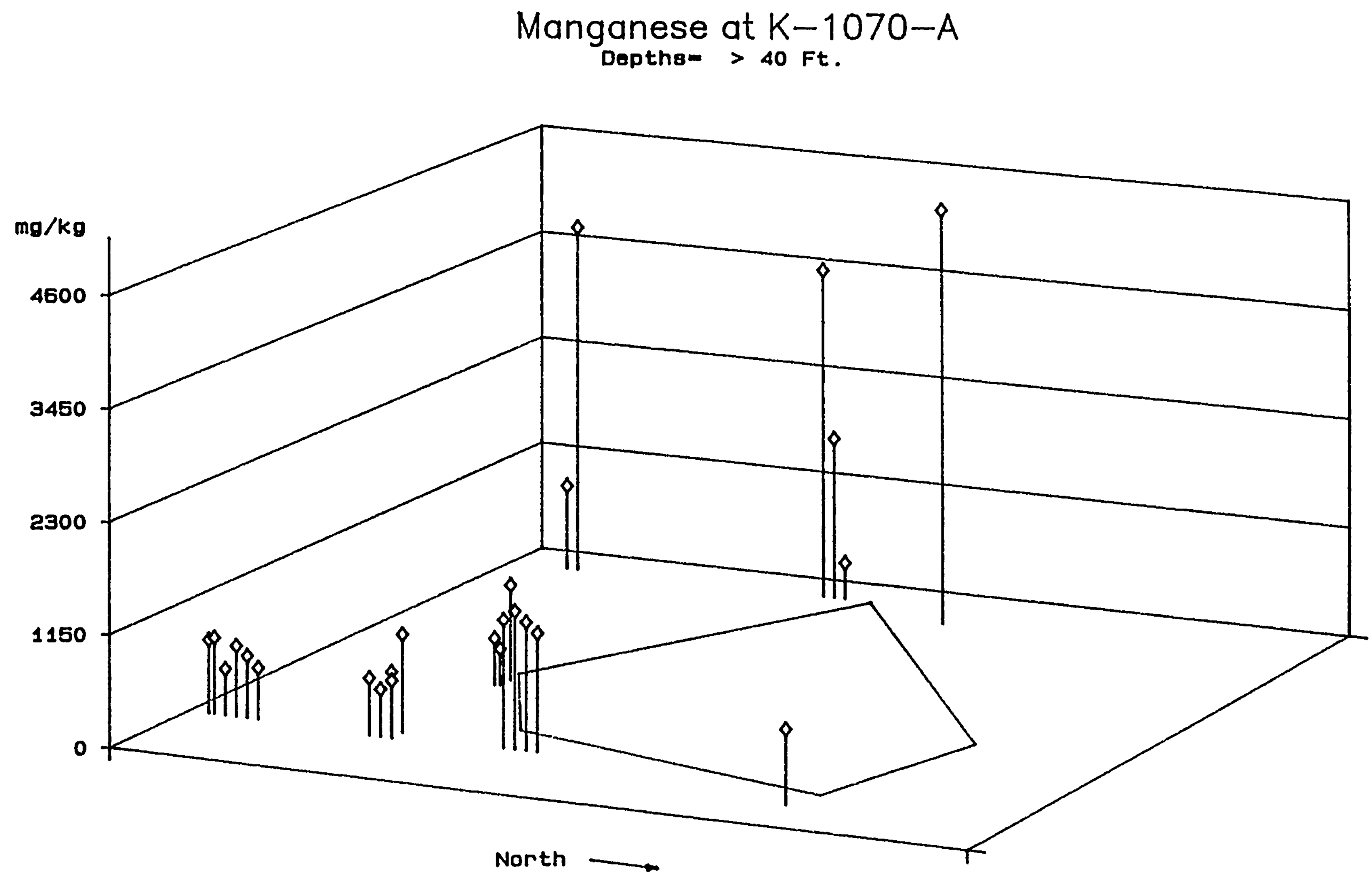
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 33. Manganese distribution in 0 to 20 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 34. Manganese distribution in 20 to 40 ft samples.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Fig. 35. Manganese distribution in samples > 40 ft.

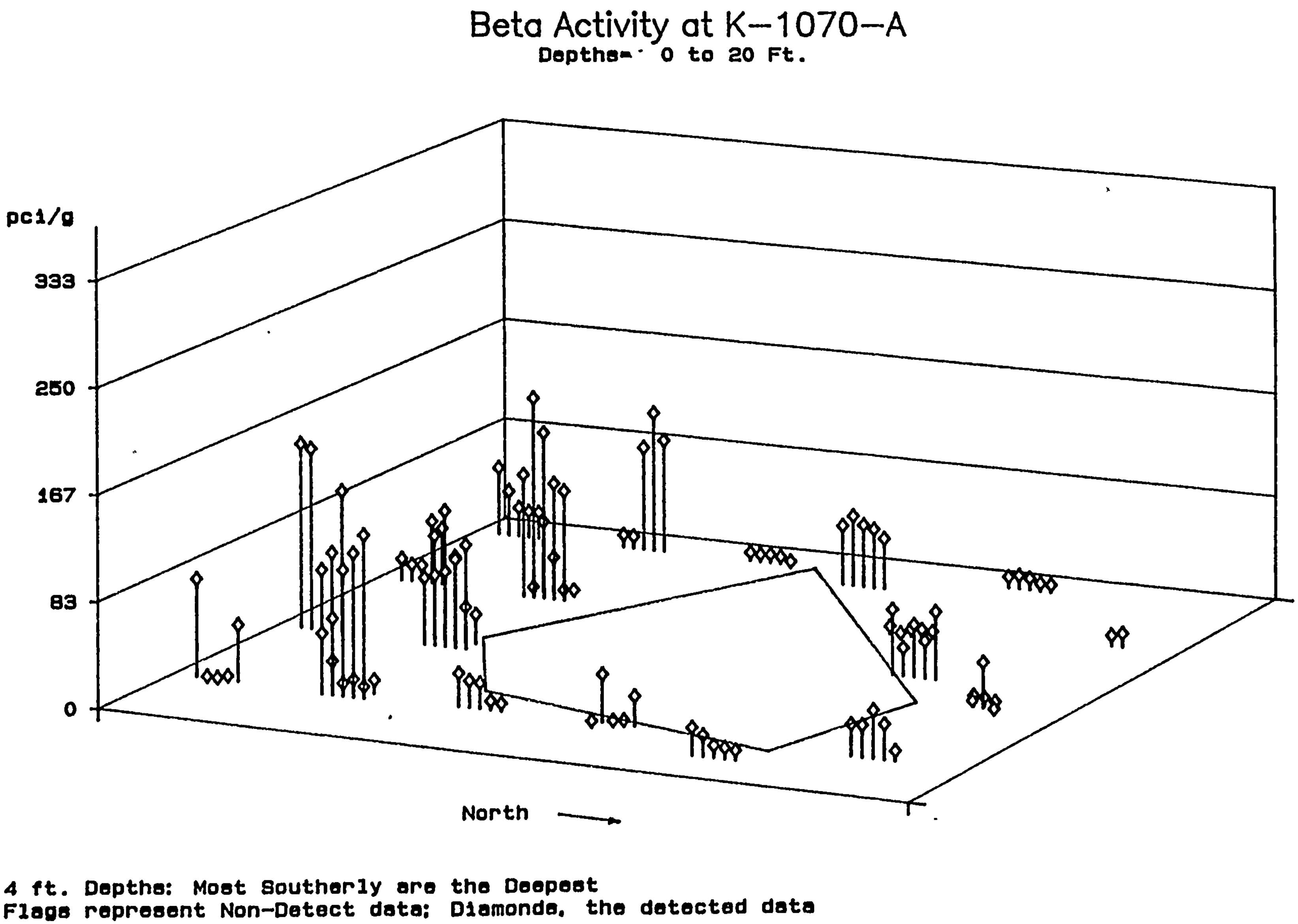


Fig. 36. Beta activity distribution in 0 to 20 ft samples.

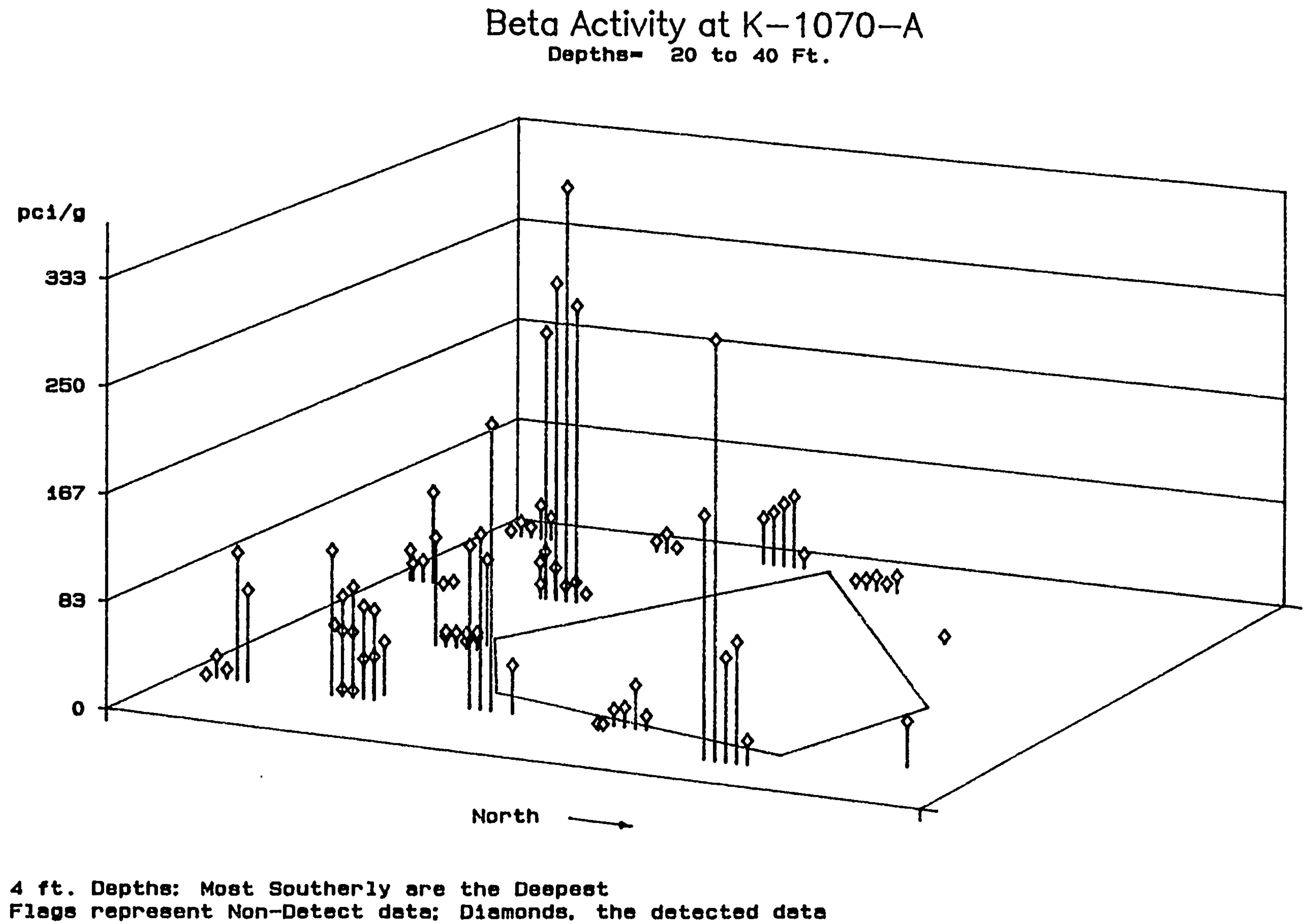


Fig. 37. Beta activity distribution in 20 to 40 ft samples.

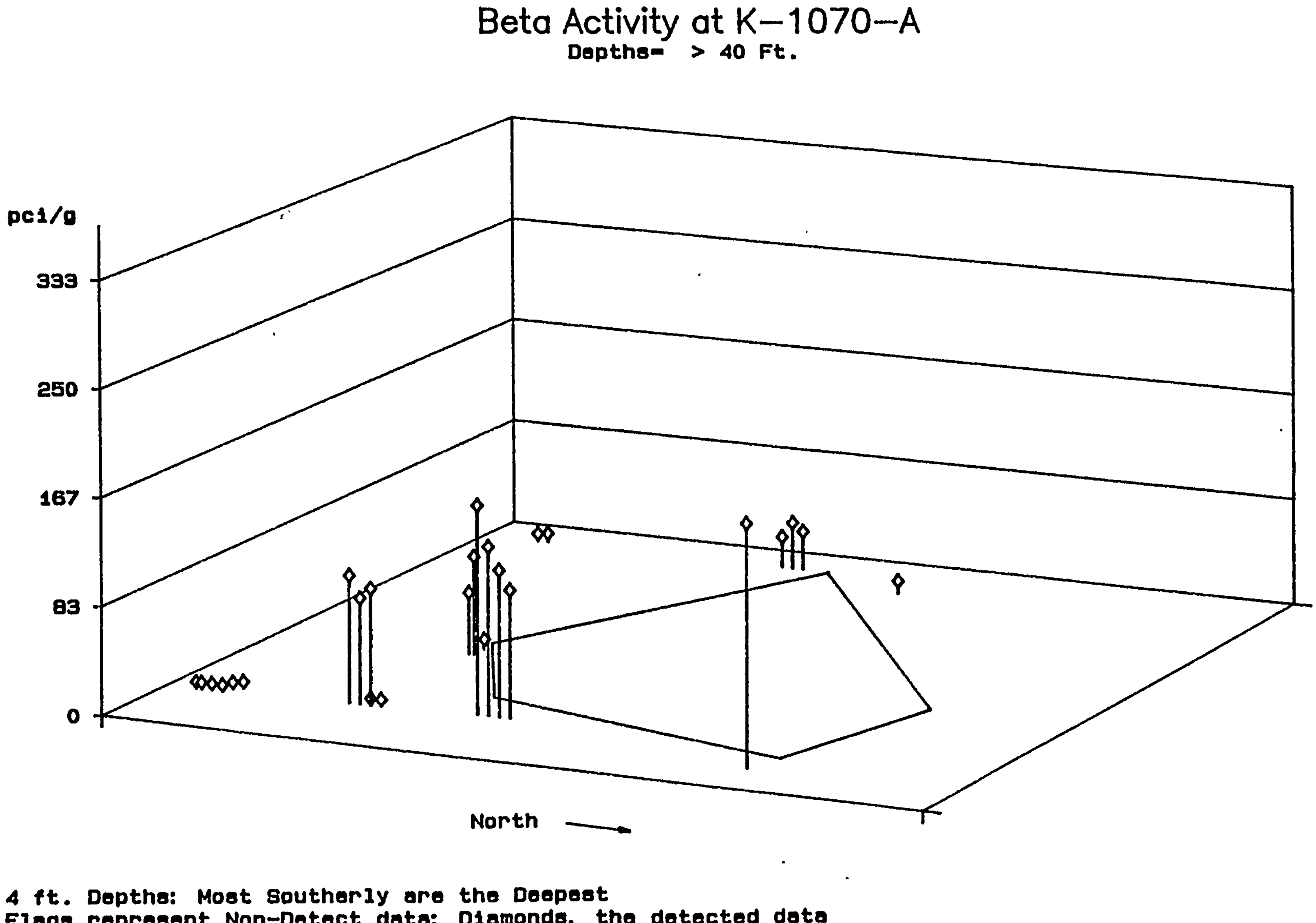


Fig. 38. Beta activity distribution in samples > 40 ft.

It was not feasible to compare average site concentrations with average background concentrations for organic compounds because organic compounds were detected in an insufficient number of samples. The limited number of samples with concentrations above the detection limit also interfered with the ability to make comparisons across depths. Table 14 lists some organic compounds present in the K-1070-A soil data. Organic compounds not in the table are known laboratory contaminants, and it is believed that they are not present at the site. Boreholes 23A and 23B have the greatest amount of organic contamination. These holes are ~100 ft southeast of the burial ground. VO analysis samples were taken from boreholes 5, 7, 12, 13B, 18, 23A, and 23B.

The evaluation of the 4-ft level samples shows that this layer of soil, possibly brought in from elsewhere as the cap over the burial ground, does not contain high levels of unexpected constituents.

There were a number of limitations that restricted the potential for the statistical evaluation of the soil data:

1. There were no laboratory duplicates taken. This prevented a separate estimate of the analytical variability from being made. However, it is hoped that this variability would be small when compared to the sampling and the small-scale spatial variability.
2. There were too few organic samples taken. This combined with the fact that only a small number of compounds were detected allowed only the detected compounds to be tabulated.
3. The background boreholes were relatively shallow, and therefore less than half the number of anticipated samples were taken.

Any further soil sampling campaign at this site should address these limitations as well as resolve the incongruities between the soil results and results of groundwater sampling and analysis in the area.

Table 14. Detected organics at K-1070-A Burial Ground

Number of Samples	Analysis	Borehole Location(s)
	Polycyclic aromatic hydrocarbons	
1	Benzo(a)anthracene	12
1	Benzo(b)fluoranthene	12
1	Benzo(a)pyrene	12
3	Pyrene 11B, 12, 14	
	Semivolatiles	
1	N-nitroso-di-n-propylamine	23A
4	Phenol	2, 7, 8, 12
2	2,5-Hexanedione	17B, 23B
	Volatiles	
1	Carbon tetrachloride	23B
3	Chloroform	5, 23B
10	Trichloroethene	23A, 23B
7	4-methyl-2-pentanone	12, 13B, 18, 23A, 23B
8	2-Propanol	5, 12, 18

6. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The purpose of this section is to supply a preliminary list of available federal and state chemical- and location-specific applicable or relevant and appropriate requirements (ARARs) that might be considered during remediation of the K-1070-A Contaminated Burial Ground. Identification of action-specific ARARs will be deferred until the WAG 10 groundwater investigation has been completed. This list of ARARs represents a compilation of potential ARARs of which subsets will be used or additional ARARs added as contamination at K-1070-A is further characterized and remedial alternatives selected.

Since the burial ground was covered with 4 ft of clean soil, direct contact of surface water with the waste material is unlikely. Thus surface-water runoff was not determined to be a primary contaminant migration pathway at this site, and surface water was not sampled during the Phase 1 RFI.[9] However, depending on results of the Phase 1 sampling program, down-gradient surface water contamination may be assessed in later phases of the investigation. Additionally, this section only addresses the contaminants detected in site soil; groundwater contamination will be considered after the WAG 10 investigation.

6.1 DEFINITIONS

Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (55 *FR* 8742, March 8, 1990).

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (55 *FR* 8742, March 8, 1990).

Requirements under federal or state law may be *either* applicable *or* relevant and appropriate to CERCLA cleanup actions, but not both. However, for compliance to be necessary, requirements must be either applicable or *both* relevant *and* appropriate to the conditions existing at a site.

Substantive requirements pertain directly to the actions or conditions at a site, while **administrative requirements** facilitate their implementation. CERCLA on-site remedial response actions must only comply with the substantive requirements of a regulation, and not the administrative requirements to obtain federal, state, or local permits [Superfund Amendments and Reauthorization Act §121(e) and Federal Facility Agreement §XXII]. In order to ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final National Contingency Plan (NCP) (55 *FR* 8756, March 8, 1990). EPA recognizes that certain of the administrative requirements, such as consultation with state agencies, reporting, etc., are accomplished through the state involvement and public participation requirements of the NCP. These administrative requirements should be observed if they are useful in determining cleanup standards at the site (55 *FR* 8757). In the case of K-1070-A, compliance with various RCRA administrative requirements is already in place and will continue (Haymore 1990).[20]

To-be-considered (TBC) guidance comprises the many criteria, advisories, guidance values, and proposed standards that are not legally binding but in the absence of federally- or state-promulgated regulations, may serve as useful guidance for setting protective cleanup levels. These are not potential ARARs.

6.2 CHEMICAL-SPECIFIC ARARs

"Chemical-specific requirements set health or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants" (53 *FR* 51437, December 21, 1988). These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or else indicate a safe level of discharge that may be incorporated when considering a specific remedial activity. In the case of K-1070-A, ARARs are listed for chemicals that are being considered for risk assessment.

6.2.1 Soil

There are no federal or state ARARs governing cleanup of contaminated soils at RCRA or CERCLA sites. RCRA has addressed land disposal of treated hazardous wastes in its land disposal restrictions (LDR) (40 CFR Part 268). However, EPA has determined that current best demonstrated available technologies listed in the LDR regulations are generally inappropriate or unachievable for CERCLA response actions (55 *FR* 8760). Therefore, EPA is proposing a separate rulemaking to establish treatment standards for disposal of contaminated soil and debris [Notice of Proposed Rulemaking (NPRM), September 1991; Final Rule expected September 1992], and these will be analyzed as ARARs or TBC guidance when available. In the interim, EPA has developed guidance for obtaining and complying with a treatability variance for soil and debris that are contaminated with RCRA hazardous wastes for which treatment standards have already been set [Office of Solid Waste and Emergency Response (OSWER) Directive 9347.3-06FS, July 1989]. Alternate treatment levels are presented for structural functional groups of organics and for ten inorganics based on actual treatment of soil and best management practices for debris. These will be considered as TBC guidance when remedial alternatives are selected and more information becomes available on waste types.

6.2.2 Other "To-Be-Considered" (TBC) Guidance

In the absence of federal- or state-promulgated ARARs, or in the case that ARARs are not adequately protective, other federal or state criteria, advisories, or guidance will be considered. EPA states a preference for reference doses (RfDs) and Carcinogen Potency Factors (CPFs) in the absence of ARARs (53 *FR* 51394) but suggests that other criteria may be considered based on the pertinence of the criteria to exposure conditions at the site and on the quality of the value.

For noncarcinogenic chemicals, EPA sets remediation goals based on "reliable toxicity information" such as RfDs (55 *FR* 8712). RfDs represent concentrations of chemicals to which the human population (including sensitive subgroups) may be exposed daily without an appreciable risk of deleterious effects during a lifetime. For known or suspected carcinogens, EPA bases remediation goals on "reliable cancer potency information" such as CPFs (55 *FR* 8712).

Available RfDs and CPFs for oral and inhalation exposures to chemicals considered for risk assessment at K-1070-A are listed in Table 15. Although low-level radioactive waste is present at K-1070-A, the isotopes have not been identified as yet. Therefore, no TBC values are listed for radionuclides other than naturally occurring uranium.

EPA has suggested cleanup values for lead in soils based on studies of blood lead levels in exposed children. EPA OSWER Directive 9355.4-02 recommends a cleanup level for soils of 500-1000 ppm lead.

Table 15. "To be considered" (TBC) guidance for soil cleanup at the K-1070-A Contaminated Burial Ground[a]

Compound	Oral		Inhalation	
	RfD[b] (mg/kg/day)	CPF[c] (mg/kg/day)$^{-1}$	RfD[b] (mg/kg/day)	CPF[c] (mg/kg/day)$^{-1}$
2-Propanol	—	—	—	—
2,5-Hexanedione	—	—	—	—
3,3-Dichlorobenzidine	—	4.5E-01	—	—
4-Methyl-2-pentanone	5.0E-02	—	2.0E-02	—
Antimony	4.0E-04	—	—	—
Arsenic	1.0E-03	5.0E-05 μ/L[d]	—	5.0E+01
Barium	7.0E-02	—	1.0E-04	—
Benzo(a)anthracene	—	1.15E+01[e]	—	—
Benzo(a)pyrene	—	1.15E+01[e]	—	—
Benzo(b)fluoranthene	—	1.15E+01[e]	—	—
Beryllium	5.0E-03	4.3E+00	—	8.4E+00
bis(2-Chloroethyl)ether	—	1.1E+00	—	1.1E+00
Boron	9.0E-02	—	—	—
Cadmium (food)	1.0E-03	—	—	—
(water)	5.0E-04	—	—	—

Table 15. "To be considered" (TBC) guidance for soil cleanup at the K-1070-A Contaminated Burial Ground[a] (continued)

Compound	Oral		Inhalation	
	RfD[b] (mg/kg/day)	CPF[c] $(mg/kg/day)^{-1}$	RfD[b] (mg/kg/day)	CPF[c] $(mg/kg/day)^{-1}$
(air)	—	—	—	6.1E+00
Carbon Tetrachloride	7.0E-04	1.3E-01	—	1.3E-01
Chloroform	1.0E-02	6.1E-03	—	8.1E-02
Chromium VI (total)	5.0E-03	—	5.7E-07	4.1E+01
Cobalt	—	—	—	—
Hexachlorobenzene	8.0E-04	1.6E+00	—	1.6E+00
Lead	—	—	—	—
Manganese	1.0E-01	—	1.1E-04	—
Molybdenum	4.0E-03	—	—	—
Nickel	2.0E-02[f]	—	—	1.7E+00[g]
N-nitroso-di-N-propylamine	—	7.0E+00	—	—
Selenium	3.0E-03[h]	—		
Silver	3.0E-03	—	—	—
Strontium[i]	—	—	—	—
Trichloroethene	—	1.1E-02	—	1.7E-02
Uranium (soluble salts)[i]	3.0E-03	—	—	—
Vanadium	7.0E-03	—	—	—
Zinc	2.0E-01	—	—	—

[a]U.S. Environmental Protection Agency, *Health Effects Assessment Summary Tables, Fourth Quarter, FY 1990*, OERR 9200.6-303-(90-4), U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, 1990.

[b]RfD = Reference dose (*Health Effects Assessment Summary Tables*) unless otherwise noted.

[c]CPF = Carcinogen potency factor (*Health Effects Assessment Summary Tables*) unless otherwise footnoted.

[d]Proposed, *Integrated Risk Information System* [data base], U.S. Environmental Protection Agency, Environmental Criteria Assessment Office, Cincinnati, Ohio, February 1991.

[e]U.S. EPA ambient water quality criteria (AWQC). Data for the AWQC are calculated for the sum of the polynuclear aromatic hydrocarbons based on a study for benzo(a)pyrene.

[f]Tested as nickel sulfate.

[g]Tested as nickel subsulfide.

[h]Based on selenious acid.

[i]Radioisotopes not identified.

6.3 RADIATION PROTECTION STANDARDS

Very few applicable standards are available for the cleanup of radioactively contaminated RCRA/CERCLA sites. The Atomic Energy Act (AEA) of 1959 and its amendments delegated authority for control of nuclear energy to EPA, the U.S. Nuclear Regulatory Commission (NRC), and DOE. In addition, certain states have regulatory authority and programs for radioactive waste. EPA regulations cover many types of activities and all types of radioactive materials, including naturally occurring and accelerator-produced radioactive material (NARM). NRC licenses the possession and use of various types of radioactive materials at certain types of facilities. Tennessee is an NRC-Agreement state, and as such has its own authority and licensing regulations. In addition, Tennessee enforces NARM standards.

DOE is authorized to control all types of nuclear materials at sites under its jurisdiction and is exempt from NRC licensing and regulatory requirements. Therefore, NRC regulations are not considered to be ARARs for CERCLA cleanup at DOE facilities.

The waste contained in the trenches and pits of K-1070-A consists of unclassified low-level radioactive solid and mixed chemical waste. An inventory of the waste is listed in the site characterization summary[9] and reproduced as Appendix B of this DETM. Most of the waste is composed of uranium- and thorium-contaminated materials; the total radioactivity is estimated to be 14 Ci. The proper definition of "mixed low-level radioactive and hazardous waste" has caused considerable debate with regard to whether such waste falls under the jurisdiction of EPA or NRC. However, EPA has published a clarification of the problem (53 *FR* 37045, September 23, 1988), as did DOE previously [52 *FR* 15937, May 1, 1987, and DOE Order 5400.3 (*Hazardous and Radioactive Mixed Waste Program*, February 22, 1989)]. In effect, mixed wastes are those containing a RCRA hazardous waste as defined in 40 CFR Part 261 and a radioactive waste subject to the AEA. RCRA regulations apply to the hazardous component of the waste and AEA regulations apply to the radioactive component. When the application of both standards is conflicting or inconsistent, RCRA yields to the AEA. Tennessee received final authorization to regulate radioactive mixed waste on July 3, 1986 (53 *FR* 37045, September 23, 1988); however, the state has not implemented any regulations or guidance relating to the handling of mixed waste.[21]

6.3.1 EPA Regulations

40 CFR Part 61 (Subpart H) addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during cleanup of K-1070-A. EPA has issued a final National Emission Standards for Hazardous Air Pollutants rule (54 *FR* 51654, December 15, 1989) which limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 CFR Part 61.92).

EPA intends to develop environmental radiation protection standards for the disposal of low-level waste (LLW) (possibly including NARM) under 40 CFR Part 193 and 764. The intent of these standards will be to protect the public health and general environment from potential adverse effects from LLW disposal. These proposed regulations may provide TBC guidance for cleanup of K-1070-A, and when promulgated, will probably be considered to be ARARs (NPRM intended September 1991; Final Rule December 1992).

6.3.2 TBC Guidance

6.3.2.1 NRC regulations

As mentioned previously, DOE is not regulated by the NRC; however, NRC regulations might provide some TBC guidance for cleanup of uranium- and thorium-contaminated materials at K-1070-A, and thus the regulations are summarized here. The standards for protection against radiation (10 CFR Part 20) are designed to limit radiation exposures from NRC-licensed activities. They provide permissible worker exposure limits for restricted areas of 1.25 rem/quarter (10 CFR Part 20.101).

The NRC has promulgated licensing requirements for land disposal of radioactive waste (10 CFR Part 61). Part 61 contains procedural requirements and performance standards applicable to any method of land disposal, with specific technical requirements for near-surface disposal of radioactive waste. Although not ARARs, the substantive requirements found in this regulation might provide TBC guidance for disposal options selected at K-1070-A; these requirements will be evaluated when remedial alternatives are selected. Title 10 CFR Part 61.41 states that concentrations of radioactive materials released to the environment in all media must not result in an annual dose exceeding 75 mrem to the thyroid and 25 mrem to total body or all other organs of any member of the public. In addition, reasonable effort must be made to maintain releases of radioactive materials to "as low as reasonably achievable." Title 10 CFR Part 61.42 states that inadvertent intruders must be protected following cessation of active institutional controls, and 10 CFR Part 61.41 stipulates that operations at land disposal facilities must be carried out in compliance with 10 CFR Part 20.

6.3.2.2 Other

Although gross alpha, beta, and gamma activity has been reported for K-1070-A, specific radionuclide isotope analyses have not been performed. Given the data limitations associated with the gross activity measurements, health effects from specific radionuclides have not been quantified. However, the EPA Office of Radiation Programs has derived slope factors for radionuclides of concern at remedial sites for each of these major exposure pathways: inhalation, ingestion, and surface irradiation.[22] These will be supplied if needed for the radiological risk assessment when radioactive isotopes are identified.

6.4 LOCATION-SPECIFIC ARARs

Location-specific requirements "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (53 *FR* 51437, December 21, 1988). Table 16 lists the major federal and state location-specific ARARs that might be pertinent to remedial actions for the K-1070-A Contaminated Burial Ground. These will be reevaluated as ARARs as the remedial alternatives are selected.

The DOE ORR is exempt from compliance with the RCRA seismic requirements of 40 FR Part 264.18 because 40 CFR Part 264.18(a) stipulates that all facilities that are located within the political jurisdictions other than those listed in Appendix VI are assumed to be in compliance for location of new TSD facilities. Tennessee is not listed in the Appendix.

Table 16. Tentative location-specific applicable or relevant and appropriate requirements for K-1070-A[a]

Location	Requirement	Prerequisite(s)	Citation
Within area affecting stream or river	Must take action to protect affected fish or wildlife resources; prohibits diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Presence of fish and wildlife resources	Fish and Wildlife Coordination Act (16 USC 661 et seq.); 40 CFR 6.302(g); TDHE Water Quality Control (Chap. 1200-4-3)
Critical habitat upon which endangered or threatened species depend	Must take action to conserve endangered or threatened species; must not destroy or adversely modify critical habitat; consultation with Department of Interior	Determination of presence of endangered or threatened species	Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 CFR 402; Fish and Wildlife Coordination Act (16 USC 661 et seq.); 33 CFR 320-330; Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA §11-26-201); Tennessee Non-Game and Endangered or Threatened Wildlife Species Conservation
Act of 1974 (TCA §70-8-101			to -112)

[a]Adapted from US EPA (1988).

However, EPA intends to propose additional floodplain and seismic restrictions for location of TSD facilities (NPRM, December 1991; Final Rule expected April 1993), and these restrictions will be incorporated into the TDHE Hazardous Waste Management regulations.[23] At that time, the TDHE seismic regulations may be ARARs for remedial actions at K-1070-A.

6.4.1 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no known designated wilderness areas, wildlife refuges, scenic rivers, or natural areas on the K-1070-A site.[20, 24]

6.4.2 Wetlands and Floodplains

There are no known wetlands on or near the K-1070-A site.[20] However, tributaries to the Clinch River and the Watts Bar Lake Embayment/Clinch River waterway have been classified for a variety of uses including domestic and industrial water supply, navigation, livestock watering and wildlife, recreation, irrigation, and fish and aquatic life (TDHE Water Quality Control Act, Chap. 1200-4-4). Ponds and other small shallow bodies of water on or near K-25 Site represent calm, well-oxygenated bodies of water that are favorable habitats for benthic and littoral zone organisms.[4]

If any remedial action is taken that would impact a nearby stream or river, the Fish and Wildlife Coordination Act and the TDHE Water Quality Control Act may contain ARARs (see Table 16).

Melton Hill Dam, located upstream of the K-25 Site on the Clinch River, and the Watts Bar Dam on the Tennessee River, located downstream, are the dams that control the flow of the Clinch River in the vicinity of the K-25 Site.[4] Although portions of the K-25 Site are located in the 100- and 500-year floodplains,[4] the K-1070-A Contaminated Burial Ground is not located in any of the floodplain areas.[20]

6.4.3 Historic Site and Archaeological Findings

There are no known registered historical buildings or archaeological findings on or near the K-1070-A Contaminated Burial Ground area.[25]

6.4.4 Rare, Threatened, or Endangered Species

There are no known rare, threatened, or endangered species that exist on the K-1070-A site.[4, 25] However, there are 16 plant species and 18 wildlife species found at or near the K-25 Site that are considered rare, threatened, or endangered. If a site investigation reveals the presence of any rare, threatened, or endangered animals or plants at the K-1070-A site, or if a remedial action might impact the critical habitat of an endangered species, the Endangered Species Act of 1973, the Tennessee Rare Plant Protection and Conservation Act of 1985, and the Tennessee Non-Game and Endangered or Threatened Wildlife Species Act of 1974 may be ARARs (Table 16).

7. PRELIMINARY RISK ASSESSMENT

This chapter examines the ability of the Phase 1 investigation to provide the data necessary to conduct a comprehensive assessment of the potential adverse human health effects from exposure to soil contamination at the K-1070-A Contaminated Burial Ground. A conservative human health-based screening of soil contaminant concentrations is employed to indicate the contaminants which pose the greatest potential for producing adverse human health effects. This screening method is used to evaluate contaminant distribution and the effectiveness of the Phase 1 investigation to adequately characterize the extent of contamination at the site. Additionally, this section includes an evaluation of the ability of the data to characterize contamination as it relates to the environmental and exposure pathways which influence the nature of exposure to site contamination. This section is concluded with a summarization of the Phase 1 data limitations affecting the production of a baseline risk assessment.

7.1 DATA EVALUATION/POTENTIAL CONTAMINANTS OF CONCERN

The evaluation of data for risk assessment is an iterative process which involves not only following set procedures, but also making decisions and assumptions concerning the data based on historical information, disposal records, and "best professional judgement." Soil data for the K-1070-A Contaminated Burial Ground were compiled by the data base manager in accordance with the specifications outlined in the *ORGDP Remedial Action Program Data Management Plan*, K/HS-232, Revision 1.[19] The following discussion addresses the primary steps in the evaluation of data for use in a risk assessment with regard to the appropriateness of the data and to identifying data limitations. As a result of the data evaluation, chemicals of potential concern are identified and compiled.

Evaluation of the analytical methods was the first step in the data evaluation process. Specificity, sensitivity, accuracy, and precision of the instruments and methods used for sample analysis were factors considered in determining the appropriateness and validity of the laboratory data. For CLP analytical results, qualifiers and codes were attached to data by the laboratory personnel. These codes are related to QA/QC controls or question the reported chemical identities and concentrations. All qualifiers and codes were addressed before a chemical was included in the screening assessment.

The potential for the adulteration of soil samples due to collection practices or laboratory preparation is evaluated prior to the use of data in risk assessment. To assure that samples were not contaminated during the acquisition and analysis processes, the data generated from the samples were compared with data generated from "blanks," as discussed in Chap. 4. The EPA considers acetone, 2-butanone (methyl ethyl ketone), methylene chloride, toluene, and phthalate esters to be common laboratory contaminants. If a blank contains detectable levels of these, sample results must be considered positive for site-related contamination only if concentrations exceed ten times the maximum amount detected in any blank. If other contaminants on the Target Compound List (TCL) are detected in the blanks, site samples must be considered positive only if concentrations are five times the maximum amount detected in any blank. Concentrations of common laboratory or other TCL contaminants did not exceed ten or five times the associated blank concentrations, respectively, for the K-1070-A Burial Ground data set. Therefore, no laboratory contaminants were evaluated for the K-1070-A data set. All laboratory contaminants for this data set are listed below in Table 17.

Table 17. Laboratory contaminants detected in K-1070-A soil data

Acetone	di-n-Octylphthalate	Methylene Chloride
bis(2-Ethylhexyl)phthalate	Diacetone Alcohol	Phenol
bis(2-Ethylhexyl)sebacate	Diethylphthalate	Phthalate Ester
2-Butanone	Dimethylphthalate	Pyrene
Butylbenzylphthalate	Dioctyl Adipate	Siloxane
di-n-Butylphthalate	2-Heptanone	

The identity and reported concentration of a TIC is questionable. Whether TICs are included in the list of potential contaminants of concern depends on the frequency of the TICs and site-specific historical information. If few TICs were reported and no historical information indicated that a TIC might be present, then they were eliminated from the risk assessment. Based on these criteria, no TICs were included as potential contaminants of concern for the K-1070-A Burial Ground.

Several metals which are not indicated to be associated with site activities are included as potential contaminants of concern. Many of these metals are indigenous in regional soils; consequently, it is difficult to discriminate definitively between naturally occurring constituents and site contaminants. In an attempt to differentiate between naturally occurring metal concentrations and those associated with site activities, a statistical comparison of the metals in downgradient and background samples was conducted. This comparison is discussed in Chap. 5. This evaluation demonstrated that levels of the common elements barium, chromium, cobalt, molybdenum, strontium, uranium, vanadium, and zinc in downgradient samples do not vary significantly from the upgradient background levels. In addition, beryllium, which has been buried at the site, does not vary significantly from background in the downgradient soil samples. Although antimony, arsenic, cadmium, and silver were not detected in enough samples to support a statistical evaluation, their distribution appears to be natural and unrelated to the site. The metals which vary significantly in excess of background levels are boron, lead, manganese, selenium, and nickel, all of which are considered potential contaminants of concern. It is unlikely that the K-1070-A Burial Ground is the source of metals; however, because there is some uncertainty as to the source, the toxic effects related to the exposure to some metals necessitates their inclusion in the screening assessment.

A primary goal of review of the Phase 1 data is to determine the ability of the analytical data to accurately represent the nature (contaminants and their concentrations) and extent of contamination in soil at the K-1070-A site. The array and depth of sampling is believed to have been adequate to identify the analytes present in K-1070-A soil. However, because there are no radiochemical data, the assessment of potential health hazards is incomplete. Additionally, known groundwater contaminants were not included as analytes in all samples; specifically, samples from borehole 11 were not analyzed for 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, 1,2-dichloroethene, or trichloroethene. Because of the hydrologic regime, these contaminants are not expected in the soil at this location; however, the inconsistency associated with the analysis of samples from this downgradient borehole is a limitation to the comprehensive assessment of the extent of contamination.

The potential contaminants of concern for the K-1070-A Contaminated Burial Ground were derived using the methodology outlined in Chap. 5 of *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual*, EPA/540/1-89/002, December 1989.[26] A list of the potential contaminants of concern is included in Table 18. Of the analytes detected in the soil samples, aluminum, calcium, copper, iron, magnesium, potassium, silicon, and sodium are naturally occurring essential nutrients that have little or no toxic effects at the detected levels and consequently are not considered potential contaminants of concern.

Table 18. Potential contaminants of concern detected in K-1070-A soil

Polycyclic aromatic hydrocarbons	
Benz(a)anthracene	
Benzo(b)fluoranthene	
Benzo(a)pyrene	
Semivolatiles	
2,5-Hexanedione	
n-Nitrosodi-n-propylamine	
Volatiles organics	
Carbon tetrachloride	
Chloroform	
Trichloroethene	
4-Methyl-2-pentanone	
2-Propanol	
Metals	
Antimony	Manganese
Arsenic	Molybdenum
Barium	Nickel
Beryllium	Selenium
Boron	Silver
Cadmium	Strontium
Chromium	Uranium
Cobalt	Vanadium
Lead	Zinc

In addition to the screening of detected contaminant concentrations, reported detection limits for nondeteced analytes were screened against available guideline values. This screening was used to determine whether the analytical method was sensitive enough for risk assessment purposes. Thus, if the detection limit was below the guideline value, no additional analyses or special analytical services may be warranted. However, if the detection limit was greater than the guideline value, a more sensitive analysis for a particular contaminant may be recommended to ensure that risks are accurately quantified in the baseline risk assessment.

Generally, the sample quantitation limits would be used when screening the detection limits; however, only contract-required quantitation limits were available for the K-1070-A data. The screening of the quantitation limits of bis(2chloroethyl)ether, 3,3-dichlorobenzidine, and hexachlorobenzene will serve to indicate whether these constituents which, although not detected in any samples, are potentially present at a concentration above acceptable levels.

7.2 DOSE-RESPONSE INFORMATION EMPLOYED IN SCREENING

The screening of contamination in soil at the K-1070-A Contaminated Burial Ground involves a comparison of contaminant concentrations to guideline values which are based on chemical- or element-specific dose-response information. Potential carcinogenic effects are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure from projected intakes and by chemical-specific dose-response data or slope factors. Potential noncarcinogenic effects are characterized by comparing projected intakes of contaminants to reference doses RfDs. The following discussion is a brief explanation of the significance of slope factors and RfDs in the context of the screening assessment.

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen (i.e., incremental or excess individual lifetime cancer risk). Cancer risk from the exposure to contamination is expressed as excess cancer risk, that is, cancer incurred in addition to normally expected rates of cancer development. An excess cancer risk of 1×10^{-6} indicates one person in 1,000,000 is predicted to incur cancer from exposure to this contamination level. Excess cancer risks falling between 1×10^{-4} and 1×10^{-6} are within the range of concern, and cancer risks above 1×10^{-4} are considered unacceptable by EPA (1989).[26]

The excess cancer risk is determined by the application of a slope factor, which is a chemical-specific value based on carcinogenic dose-response data. The slope factors and the estimated daily intake of site constituents, averaged over a lifetime of exposure, are used to estimate the incremental risk of an individual developing cancer. Because the slope factors are the upper 95th percentile confidence limit on the probability of a carcinogenic response, the carcinogenic risk estimate represents an upper-bound estimate. The screening of the carcinogenic toxicity of contaminants is based on determining the samples in which concentrations producing a risk of 1×10^{-5} or greater were detected.

Slope factors used in the evaluation of risk from exposure to contaminants in K-1070-A soil are listed in Table 19. Slope factors are from *Health Effects Assessment Summary Tables* (EPA, 1990)[22] and the *Integrated Risk Information System* data base (EPA, 1990).[27] Slope factors are not currently available for all potential contaminants of concern. Several contaminants are not indicated by epidemiological studies to be carcinogenic; consequently, these contaminants do not have slope factors. Furthermore, slope factors are not available for several potential contaminants of concern because their carcinogenicity has not been determined. These contaminants may contribute to carcinogenic effects from exposure to the soil, but their effect cannot be quantified. The unavailability of slope factors precludes a comprehensive screening assessment of the risk from exposure to site contaminants. The toxicity information available limits the screening of carcinogenic contaminants to the arsenic, beryllium, cadmium, and chromium, which is a definite limitation to the assessment of risk from exposure to soil at the site.

Table 19. Available slope factors for K-1070-A soil contaminants

Analyte	Ingestion slope factor $(mg/kg/day)^{-1}$	Inhalation slope factor $(mg/kg/day)^{-1}$
Arsenic	1.75	50.000
Beryllium	4.3000	8.4000
Bis(2-chloroethyl)ether	1.1000	1.1000
Cadmium	ND	6.1000
Carbon tetrachloride	0.1300	0.1300
Chloroform	0.0061	0.0810
Chromium (VI)	ND	41.000
3,3'-Dichlorobenzidine	0.4500	ND
Hexachlorobenzene	1.6000	1.6000
N-Nitrosodi-N-propylamine	7.0000	ND
Trichloroethene	0.0110	0.0170

ND = No data available.

Noncarcinogenic effects are evaluated by comparing an exposure level over a 5-year period with an RfD derived for chronic exposure. The available RfDs given in Table 20 for the contaminants of concern in K-1070-A soil are from *Health Effects Assessment Summary Tables* (EPA, 1990)[22] and the *Integrated Risk Information System* data base (EPA, 1990).[22] The RfD is representative of the daily exposure level that causes no deleterious effects during a lifetime. A chronic exposure duration is considered to be from 7 years to a lifetime. The use of the chronic RfD assures that the screening is based on a conservative evaluation of adverse health effects. To evaluate the noncarcinogenic effects of exposure to soil contaminants, the dose is compared to the RfD. The noncarcinogen hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive populations to experience adverse health effects. If the exposure level (dose) exceeds this threshold (i.e., if dose/RfD exceeds 1), there may be concern for potential noncarcinogenic health effects.

RfDs are not available for some of the potential contaminants of concern. These contaminants may contribute to noncarcinogenic effects from exposure to the soil, but their effect cannot be quantified. Therefore, a comprehensive screening of the noncarcinogenic effects from exposure to soil at K-1070-A is not possible.

7.3 CONTAMINANT SCREENING

The screening of K-1070-A soil is a comparison of contaminant concentrations detected in soil to a guideline value, following the methodology outlined in the *Data Analysis Approach Report for K-1407-B Holding Pond and K-1407-C Retention Basin*, K/ER-23.[28] The guideline value is derived from very conservative exposure scenarios (high intake rates) and chemical/element-specific dose-response information.

Table 20. Available reference doses for K-1070-A soil contaminants

Analyte	Ingestion reference dose (mg/kg/day)$^{-1}$	Inhalation reference dose (mg/kg/day)$^{-1}$
Antimony	0.00040	ND
Arsenic	0.00100	ND
Barium	0.07000	0.6000100
Beryllium	0.00500	ND
Boron	0.09000	ND
Cadmium	0.00050	ND
Carbon tetrachloride	0.00070	ND
Chloroform	0.01000	ND
Chromium (VI)	0.00500	0.60000057
Hexachlorobenzene	0.00080	ND
Manganese	0.10000	0.60001100
4-Methyl-2-pentanone	0.05000	0.60200000
Molybdenum	0.00400	ND
Nickel	0.02000	ND
Silver	0.00300	ND
Vanadium	0.00700	ND
Zinc	0.20000	ND

ND = No data available.

The screening of the contaminants detected during the Phase 1 investigation was initiated to indicate the contaminants which may pose an imminent health hazard. Additionally, screening indicates the contaminants most likely to influence risk management decisions and cleanup goals. This prioritization of contaminants may be used to emphasize analytes in future soil samples that should be considered critical to the investigation of the site. It should be emphasized that screening is not used to eliminate any contaminants from consideration in future risk assessment. An evaluation of all contaminants detected in soil samples from the K-1070-A Contaminated Burial Ground will be included in the baseline risk assessment. Therefore, all contaminants detected at the site during preliminary phases of sampling must be included as analytes in subsequent phases of the investigation.

The screening of contamination at K-1070-A is not intended to serve as a quantitative assessment of the potential adverse health effects incurred from exposure to soil at the site. The conservative exposure scenarios used in screening do not consider site-specific factors influencing the exposure to site contamination; consequently, the screening scenarios do not represent possible circumstances of exposure which may occur at the site. There are no activities currently taking place that involve the potential for exposure to soil contamination at K-1070-A.

The parameters applied to the screening of soil data from the K-1070-A Contaminated Burial Ground are defined in the following discussion. A listing of the exposure pathways applied in the screening assessment is included as well as the derivation of the contaminant concentrations in air for screening against inhalation guideline values. Additionally, the duration of exposure and intake rates employed in the calculation of carcinogenic and systemic toxicity guideline values are detailed. Lastly, the guideline values are listed for carcinogenic and systemic toxicity, and the screening results are presented.

7.3.1 Exposure Pathways

In order to indicate the pathway(s) which present the greatest potential for the incidence of adverse health effects, screening is conducted for all exposure pathways for which exposure at the site is conceivable. Because the conditions of exposure and the slope factor and/or RfD vary with the nature of intake (ingestion, inhalation, dermal contact, and/or external exposure to radiation) the guideline value is different for each exposure pathway. The screening of contaminants is conducted against ingestion and inhalation guideline values. Screening against guideline values derived from dermal exposure is not considered, due to the ineffectiveness of this pathway relative to screening based on oral and inhalation exposure. In addition, dermal exposure at the site is not likely to occur.

Screening against ingestion guideline values is straightforward; contaminant concentrations detected in each soil sample are compared to the guideline values. However, because contaminant concentrations in air have not been measured, the concentrations applied in the inhalation screening must be calculated from soil concentrations. The following is an explanation of the derivation of air concentrations from measured soil concentrations.

The evaluation of the inhalation exposure to soil contaminants is evaluated by considering the suspension of site soil by wind. The fugitive dust generated is estimated by the method described by Eckerman and Young (INTEGRATED-0707, 1980).[29] The contamination in the air generated by the wind is determined by applying an empirically derived resuspension factor for wind-borne contamination of 2×10^{-7}/m (Sehmel, 1984) to the contaminant levels in surface soil.[30] The resuspension factor is the ratio of the concentration in air (m^3) to the concentration on the surface (m^2).

For calculating the exposure concentrations in air due to dust, the contaminant levels in the soil must be converted from mg/kg for metals to mg/m^3 for use in this equation. The density of soil reported in the Blount County Soil Survey (series 1953, No. 7), 1.6×10^6 g/m^3, is applied to convert the representative surface soil concentrations.[31] This equation determines the amount of contaminant per m^3 of soil:

$$1.6 \times 10^6 \text{ g/m}^3 \times \text{concentration mg/g soil} = \text{mg contaminant/m}^3$$

It is assumed that only a thin veneer of soil is actually releasing dust due to wind; therefore, only the amount of contaminants in the surface layer should be used to determine concentrations in air. The concentration of the contaminant at the surface is represented by assuming the depth of the soil surface layer to be 1 cm. Therefore, the contaminant "density" (the amount of contaminant per m^3) is multiplied by 0.01 m to estimate the surface soil contaminant level (mg/m^2):

$$\text{mg contaminant/m}^3 \times 0.01 \text{ m} = \text{concentration in surface layer of soil (mg/m}^2\text{)}$$

The concentration of the contaminant per m^2 of the soil surface is converted to a concentration in air by the application of the resuspension factor. Resuspension factors are determined empirically and represent the amount of surface material (mg/m^2) that becomes airborne (mg/m^3) due to specific activities. The resuspension factor due to wind reported in Sehmel (1984) ranges from 3×10^{-4}/m to 9×10^{-11}/m (ref. 30). A value of 2×10^{-7}/m is applied in the inhalation screening of contaminants. Using the quantity of surface material suspended due to wind and the estimated amount of contaminant per surface area of soil determined in the calculations above, the contaminant's concentration in air is determined:

$$(2 \times 10^{-7}/\text{m}) \times \text{surface concentration (mg/m}^2) = \text{concentration in air(mg/m}^3)$$

This concentration is compared to screening values based on contaminant inhalation toxicity.

Several assumptions have been made in the inhalation screening of contaminant concentrations. To assure a conservative screening assessment, a complete transfer of soil contamination to wind-generated dust was assumed. Therefore, reactions affecting contaminant concentrations in dust, such as volatilization previous to suspension, were ignored. This assumption, while reasonable for inorganics and some organics with low solubilities and high partition coefficients, is not accurate for volatiles. However, there is no way to determine the concentration of volatiles remaining in suspended particles accurately. It is also difficult to ascertain concentrations in air due to volatilization of contaminants from the soil. If it were possible to quantify the concentration of volatiles in dust and in the air due to volatilization accurately, it would be proper to consider inhalation exposure to both. Because this is not practical, we have included a screening based on inhalation exposure to contaminants only in dust, while assuming their complete absorption to dust in order to account for exposure to volatiles.

7.3.2 Carcinogenic Screening

The calculation of guideline values follows the methodology outlined in the *Data Analysis Approach Report for K-1407-B Holding Pond and K-1407-C Retention Basin*, K/ER-23.[28] For screening carcinogenic toxicity the exposure model assumes a lifetime duration of exposure. The exposure model employs the body weight of a 70-kg adult, an ingestion rate of 0.001 kg of soil per day, and an inhalation rate of 20 m^3/day (ref. 3). Guideline values used in the screening of carcinogenic contaminants are listed in Table 21.

The results of the screening for carcinogenic toxicity are displayed in Table 22. The results are presented as a ratio of samples in which concentrations equal to or greater than the guideline value were detected to the total number of samples analyzed for the contaminant. The ratios for each exposure pathway are presented by analyte and the relative depth of the sample. Samples taken from 4 ft or less are considered surface samples, and subsurface soil is represented by samples taken at depths below 4 ft. Samples taken from all background sampling stations (BH02, BH07, BH13, and BH19) were excluded from the screening.

The screening of the carcinogenic contaminants against ingestion guideline values indicates the potential risk will be dominated by the effects of exposure to beryllium. Of the 213 surface and subsurface samples analyzed for beryllium, concentrations equal to or greater than the ingestion guideline value were detected in 207 samples. There is no deviation from this trend relative to sample depth.

Table 21. Guideline values for carcinogenic screening

Analyte	Ingestion (mg/kg/day)	Inhalation (mg/m^3)
Arsenic	0.4000	0.0000001
Beryllium	0.163	0.0000004
Bis(2-chloroethyl)ether	0.636	0.0000032
Cadmium	NA	0.0000006
Carbon tetrachloride	5.380	0.0000269
Chloroform	115.000	0.0000432
Chromium (VI)	ND	8.54E-8
3,3'-Dichlorobenzidine	1.560	NA
Hexachlorobenzene	0.438	0.0000022
N-Nitrosodi-N-propylamine	0.100	NA
Trichloroethene	63.600	0.0002060

NA = Not applicable.
ND = No data available.

Table 22. Frequency of carcinogenic soil contaminants exceeding guideline values

Analyte	Ingestion	Inhalation
Surface soil		
Arsenic	18/18	18/18
Beryllium	18/18	18/18
Bis(2-chloroethyl)ether	0/0	0/0
Cadmium	NA	18/18
Carbon tetrachloride	0/5	0/5
Chloroform	0/5	0/5
Chromium (as VI)	NA	18/18
3,3'-Dichlorobenzidine	0/0	NA
Hexachlorobenzene	0/0	0/0
N-Nitrosodi-N-propylamine	0/0	NA
Trichloroethene	0/5	0/5
Subsurface soil		
Arsenic	195/195	195/195
Beryllium	189/195	191/195
Bis(2-chloroethyl)ether	19/19	18/19
Cadmium	NA	195/195
Carbon tetrachloride	0/51	0/51
Chloroform	0/51	0/51
Chromium (as VI)	NA	195/195
3,3'-Dichlorobenzidine	19/19	NA
Hexachlorobenzene	19/19	19/19
N-Nitrosodi-N-propylamine	19/19	NA
Trichloroethene	0/51	0/51

NA = Not applicable.

Inhalation screening results indicate that arsenic, beryllium, and cadmium would be likely to contribute to the potential cancer risk from exposure if this pathway were viable. All surface and subsurface samples analyzed for arsenic and cadmium contained concentrations that were equal to or in excess of the inhalation guideline value, and only four subsurface beryllium samples were below the inhalation guideline value.

The carcinogenic screening demonstrates that the extent of contamination in the K-1070-A Contaminated Burial Ground has been sufficiently delineated for those analytes included in this evaluation to support a comprehensive assessment of the risk from exposure to site soil. However, soil samples were not analyzed for radioisotopes. Considering the history of the K-25 Site, this represents a gap in the characterization of site contamination; consequently, it is not possible to conduct a complete assessment of the excess cancer risk incurred from exposure to site soil. Additionally, the screening results based on the quantitation limits (QLs) for the four analytes not detected, bis(2-chloroethyl)ether, 3,3-dichlorobenzidine, hexachlorobenzene, and n-nitrosodi-n-propylamine, indicate that QLs were too high to ensure the detection of potentially harmful concentrations. Although these contaminants are not indicated by disposal inventories to be expected in site soil, the inadequacy of the detection limits will contribute to the uncertainty of the risk assessment.

7.3.3 Systemic Toxicity Screening

The screening for systemic toxicity employs an exposure duration of 5 years. The exposure model for systemic toxicants employs a body weight of a 16-kg child, an ingestion rate of 0.0002 kg of soil per day, and an inhalation rate of 20 m^3/day (EPA, 1989).[3] Guideline values used in the screening of the concentrations of systemic toxicants are listed in Table 23.

The results of the screening for systemic toxicity are included in Table 24. Only arsenic exceeded the ingestion guideline values. In the inhalation screening of the systemic toxicants, barium and manganese exceeded guideline values.

7.4 DATA LIMITATIONS

Because regional background samples are not available, the distinction between naturally occurring metals and site-related metal contamination is difficult. Therefore, all are considered as potentially related to the site.

Contaminant characterization is deemed inadequate for bis(2-chloroethyl)ether, 3,3-dichlorobenzidine, hexachlorobenzene, and n-nitrosodi-n-propylamine because all QLs are greater than the chemical-specific health-based reference concentrations.

Radioactive isotopes were not included in the analysis of K-1070-A soil samples, preventing the evaluation of potential risk from exposure to radiation from individual radionuclides. A thorough assessment of the potential risk posed by contaminants at K-1070-A is therefore not possible.

Table 23. Guideline values for the systemic toxicity of K-1070-A soil contaminants

Analyte	Ingestion (mg/kg)	Inhalation mg/m^3
Antimony	32	NA
Arsenic	80	NA
Barium	5600	0.00008
Beryllium	400	NA
Boron	7200	NA
Cadmium	40	NA
Carbon tetrachloride	56	NA
Chloroform	800	NA
Chromium (VI)	400	0.0000046
Hexachlorobenzene	64	NA
Manganese	8000	0.00009
4-Methyl-2-pentanone	4000	0.01600
Mercury	24	0.00007
Molybdenum	320	NA
Nickel	1600	NA
Silver	240	NA
Vanadium	560	NA
Zinc	16000	NA

NA = Not applicable.

Table 24. Frequency of systemic toxicants in soil exceeding guideline values

Analyte	Ingestion	Inhalation
Surface Soil		
Antimony	0/18	NA
Arsenic	0/18	NA
Barium	0/18	17/18
Beryllium	0/18	NA
Boron	0/18	NA
Cadmium	0/18	NA
Carbon tetrachloride	0/5	NA
Chloroform	0/5	NA
Chromium (VI)	0/18	18/18
Hexachlorobenzene	0/0	NA
Manganese	0/18	18/18
4-Methyl-2-pentanone	0/5	0/5
Mercury	0/18	0/18
Molybdenum	0/18	NA
Nickel	0/18	NA
Silver	0/18	NA
Vanadium	0/18	NA
Zinc	0/18	NA
Subsurface Soil		
Antimony	0/195	NA
Arsenic	2/195	NA
Barium	0/195	129/95
Beryllium	0/195	NA
Boron	0/195	NA
Cadmium	0/195	NA
Carbon tetrachloride	0/51	NA
Chloroform	0/51	NA
Chromium (VI)	0/195	195/195
Hexachlorobenzene	0/19	NA
Manganese	0/195	195/195
4-Methyl-2-pentanone	0/52	0/52
Mercury	0/195	0/195
Molybdenum	0/195	NA
Nickel	0/195	NA
Silver	0/195	NA
Vanadium	0/195	NA
Zinc	0/195	NA

NA = Not applicable.

Additionally, known groundwater contaminants were not included as analytes in all samples; specifically, samples from borehole 11 were not analyzed for 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, 1,2-dichloroethene, or trichloroethene. Because of the hydrologic regime, these contaminants are not expected in the soil at this location; however, the inconsistency associated with the analysis of samples from this downgradient borehole is a limitation to the comprehensive assessment of the extent of contamination.

Dose-response information for many of the constituents is not available, limiting the screening assessment of adverse health effects. Additionally, slope factors and RfDs are not available for all exposure pathways for all constituents; exposure to contaminants without slope factors or RfDs cannot be comprehensively quantified. A major limitation to the comprehensive quantification of risk from exposure to contamination at K-1070-A is the lack of chemical-specific slope factors and RfDs for all exposure pathways and contaminants. Therefore, the total risk resulting from the exposure to contaminants at the site cannot be determined.

The evaluation of environmental pathways at the K-1070-A Contaminated Burial Ground is restricted to the consideration of soil contamination. The K-1070-A environmental pathway evaluation is not complete until the human health consequences of the potential transport of contamination via groundwater are considered. The evaluation of groundwater environmental and exposure pathways will be included in the WAG 10 investigation.

8. CONCLUSIONS AND RECOMMENDATIONS

The soil investigation at the K-1070-A Contaminated Burial Ground found the area included in the soil survey relatively free of materials from the disposal area. Consequently, soil does not pose an imminent threat to human health or the environment. Additionally, the physical characterization of the site suggests that the greatest potential for the migration of contaminants from the site is via groundwater. It is recommended that at this time no further soil characterization be preformed at the K-1070-A Contaminated Burial Ground, pending the results of the groundwater investigation. On completion of the groundwater investigation, the Phase 1 soil investigation results will be integrated with findings of the WAG 10 investigation to determine if additional soil sampling is necessary. There are several limitations to the Phase 1 soil investigation which will be addressed in the event that additional soil characterization is required:

- Hydrologic conditions suggest that the path which leachate follows to the bedrock aquifer is not likely to result in the lateral spread of contaminants in the unconsolidated zone. As a result, the extent of contaminant migration from the site may not be represented by the soil samples taken for this investigation. Therefore, during any future soil sampling efforts at the site an attempt will be made to acquire samples closer to the area of contaminant deposition.

- Many of the metals detected in soil and included as potential contaminants of concern are indigenous in regional soils. Four samples were taken for background at this site; however, there is a lack information regarding regional concentrations for naturally occurring metals. Consequently, it is difficult to discriminate between indigenous metals and site contaminants. Due to the uncertainty of the source and the carcinogenic and/or systemic toxic effects related to exposure to these metals, they must be included in the risk assessment.

- To quantify the migration potential of contaminants, soil parameters influencing transport, such as particle-size distribution, porosity, soil pH, oxidation-reduction potential, cation exchange capacity, mineralogy, and organic carbon fraction, must be determined.

- Radioactive contaminants are known to have been buried at the site; however, soil samples were not analyzed for radionuclides. If additional soil sampling is conducted, analysis for specific radioactive isotopes should be included.

- Contaminant characterization is deemed inadequate for bis(2-chloroethyl)ether, 3,3-dichlorobenzidine, hexachlorobenzene, and n-nitrosodi-n-propylamine because all QLs are greater than the chemical-specific health-based reference concentrations.

- Known groundwater contaminants were not included as analytes in samples from borehole 11. Because of the hydrologic regime these contaminants are not expected in the soil at this location; however, the inconsistency associated with the analysis of samples from this downgradient borehole is a limitation to the comprehensive assessment of the extent of contamination.

- Dose-response information for many of the constituents is not available, limiting the screening assessment of adverse health effects. Therefore, the total risk resulting from the exposure to contaminants at the site cannot be determined.

- The evaluation of environmental pathways at the K-1070-A Contaminated Burial Ground is restricted to the consideration of soil contamination. The K-1070-A environmental pathway evaluation is not complete until the human health consequences of the potential transport of contamination via groundwater are considered. The evaluation of groundwater environmental and exposure pathways will be included in the WAG 10 investigation.

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Appendix A

BOREHOLE LOGS

This appendix reproduces the borehole logs for the 22 boreholes drilled at the K-1070-A Contaminated Burial Ground. Procedures for preparing the borehole log, as outlined in the Field Observation Report for K-1070-A (K/ER-7), are presented first.

PREPARATION OF DRILLING/BORING LOG

Discussion

This procedure outlines the information that should be included on a standard form when logging boreholes in conjunction with split-barrel sampling of soils. The intent of this procedure is to ensure a reasonable degree of uniformity and information on forms.

Equipment

- Munsell Color Chart (for soils)
- Geologic Society of America (GSA) Rock Color Chart
- Magnifying lens
- Ballpoint pen (permanent)
- Total depth indicator
- Engineer scale or ruler
- Appropriate soil classification chart
- Borehole Summary Information form

Procedure

1. Record preliminary borehole summary information: name, date, project, borehole number, location, rig type, auger/bit size, and sample type (split-barrel).

2. Texture and tectural changes (including fossil zones and lithologies) should be depicted as sharp discontinuity or gradational change. Where uncertainty exists, the boundary line should be portrayed with dashed, wavy, or slanted lines.

3. Sample interval, depth, and number of blows per unit length should be recorded in the appropriate columns. The Description column should contain tectural, lithologic, and color descriptions of the auger cuttings and sample intervals. The descriptions of unconsolidated material should include reference to typical names and group symbols from an appropriate soil classification chart, plus any other geologic terminology of significance, and comments on the water characteristics (where water first appears in the section, which soils are saturated, etc.). Record the grain size and the specific scale used to estimate grain size. Record the consistency strength of clays and sands based on blows per foot. Color or color changes of soils should be recorded by utilizing the Munsell Color Chart or the GSA Rock Color Chart.

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth / D.D. Folse		Date 04/06/89	Page 1 of 1
Hole No. 2	Sample Interval	Total depth 17.4	Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates		Rig Type CME 450 All Terrain Drill Rig	
Project K-1070-A	Data Verified By		Date Verified

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2 1 1 1			Clay, plastic, soft	5YR 4/4 Reddish brown
4	1 5 8 14			Clay, plastic, soft to medium stiff, large quantities of mixed chert at 3.75'	5YR 5/8 Yellowish red
6	5 11 13 12			Same	
8	8 13 15 18			Same	
10	14 22 13 14			Clay, plastic, mixed chert fragments	5YR 5/8 Yellowish red
12	4 7 8 10			Same	
14	5 11 11 14			Clay, plastic, weathered chert organic streaks & limonite	5YR 5/8 Yellowish red
16	5 13 14 21			Clay, plastic, very stiff, weathered chert fragments	5YR 5/8 Yellowish red
18	10 8 25/.4				
20					
22					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth / D.D. Folse Date 04/06/89 Page 1 of 2

Hole No. 3 Sample Interval _____ Total depth 41.3 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By _____ Date Verified _____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 4, 5, 5			Clay, plastic, soft to medium stiff, mixed chert with organic streaks	5YR 4/4 Reddish brown
4	2, 4, 5, 4			Clay, plastic, soft to medium stiff, mixed chert with minor amounts of organic streaking	5YR 5/8 Yellowish red
6	4, 6, 10, 11			Clay, plastic, medium to stiff, numerous mixed white chert fragments	5YR 5/8 Yellowish red
8	11, 10, 11, 14			Clay, plastic, stiff	5YR 5/8 Yellowish red
10	10, 12, 17, 20			Clay, stiff to very stiff, large amounts of mixed chert fragments	5YR 5/8 Yellowish red
12	7, 10, 11, 15			Clay, medium to very stiff, large amounts of mixed chert fragments, very pale brown streaks 10YR 8/4 Very pale brown	5YR 5/8 Yellowish red
14	7, 12, 14, 19			No sample	
16	7, 11, 15, 18			Clay, plastic, medium to very stiff, larger chert fragments	5YR 5/8 Yellowish red
18	2, 4, 4, 5			Clay, plastic, soft to medium, damp, shaly-clay @ 17.7'	5YR 5/8 Yellowish red
20	2, 5, 11, 8			Clay, plastic, soft to stiff, major amounts of chert fragments @ 19.9'	5YR 5/8 Yellowish red
22	3, 4, 4, 5			Clay, soft to medium, shaly @ 21.5', predominant organic staining/streaking, @ 20.2 to 20.4', mixed chert with minor amounts of well sorted sand	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth / D.D. Folse / V. Patania Date 04/06/89 Page 2 of 2

Hole No. 3 Sample Interval ____ Total depth 41.3 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	2 10 10 9			Same, soft to stiff, larger amounts of chert fragments @ 23.5'	5YR 5/8 Yellowish red
26	2 4 4 5			Same, soft to medium, with minor amounts of mixed shale appearing	5YR 5/8 Yellowish red
28	3 4 4 5			Same, soft to medium, with some cross bedded shaly layers	5YR 5/8 Yellowish red
30	7 7 8 7			Clay, plastic, medium to stiff, organics @ 29.9' intermixed with chert fragments and very weathered shale	5YR 5/8 Yellowish red
32	2 2 3 5			Clay, plastic, soft to medium, minor amounts of organics with some intermixed poorly sorted sand @ 30.2'	5YR 5/8 Yellowish red
34	2 4 4 7			Clay, soft to medium, predominant organic staining/streaking from 32.0 to 32.5', large chert fragments, olive yellow shale from 33.5 to 34.0'	5YR 5/8 Yellowish red
36	2 2 11 11			Clay, soft to stiff, sample saturated, white friable shale @ 35.0', some cross bedding in shale with minor amounts of sand	5YR 5/8 Yellowish red
38	13 22 9 10			Clay, stiff to very stiff, mixed sand and large chert fragments	5YR 5/8 Yellowish red
40	8 8 22 14			Same	5YR 5/8 Yellowish red
42	5 8 15/.3			Same, medium to hard, refusal @ 41.3', refusal material chert	5YR 5/8 Yellowish red
44					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Quillen Date 04/14/89 Page 1 of 3
Hole No. 4 Sample Interval ______ Total depth 50.2 Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	4, 4, 5, 5			Clay, soft to medium, 1" topsoil then grading to mixed dolostone with organics	5YR 4/6 Yellowish red
4	3, 4, 4, 5			Clay, plastic, soft to medium, organic streaks with some sand	5YR 4/6 Yellowish red
6	4, 8, 6, 7			Clay, plastic, medium to stiff, organic streaking with dolostone fragments	5YR 4/6 Yellowish red
8	4, 5, 6, 8			Same	5YR 5/8 Yellowish red
10	4, 6, 7, 10			Clay, soft to stiff, organics, dolostone and chert fragments, sample moist	5YR 5/8 Yellowish red
12	4, 6, 7, 9			Clay, soft to stiff, organics with mixed chert fragments	5YR 5/8 Yellowish red
14	3, 5, 6, 8			Clay, same	5YR 5/8 Yellowish red
16	3, 5, 10, 10			Clay, soft to stiff, iron staining, organic streaks, mixed weathered shale and chert fragments	5YR 5/6 Yellowish red
18	5, 5, 6, 9			Clay, medium to stiff, organic streaks, mixed weathered shale and chert framents	5YR 5/6 Yellowish red
20	3, 9, 11, 12			Clay, soft to stiff, same	5YR 5/6 Yellowish red
22	3, 5, 6, 7			Clay, plastic, soft to medium, mixed chert fragments with shaly layers, some sand	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Quillen Date____ Page 2 of 3

Hole No. 4 Sample Interval____ Total depth 50.2 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ____ Date Verified____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	6, 5, 14, 20			Clay, plastic, medium to very stiff, chert layer @ 24', same as above	5YR 5/8 Yellowish red
26	5, 25, 21, 10			Clay, medium to very stiff, chert from 24.0 to 25.5' followed by clay	5YR 5/8 Yellowish red
28	6, 5, 7, 6			Clay, medium to stiff, same as above	5YR 5/8 Yellowish red
30	7, 8, 6, 8			Clay, medium to stiff, chert and weathered shaly layers	5YR 6/8 Reddish yellow
32	3, 4, 5, 6			Clay, very plastic, soft to medium, organics, chert fragments and weathered shale	5YR 6/8 Reddish yellow
34	2, 3, 4, 4			Clay, very plastic, soft, organic streaks with weathered shale	5YR 5/8 Yellowish red
36	2, 3, 2, 5			Clay, very plastic, soft to medium, large amounts of weathered shale	5YR 5/8 Yellowish red
38	1, 2, 2, 3			Clay, very plastic, same as above	5YR 5/8 Yellowish red
40	3, 4, 4, 4			Clay, soft, same as above	5YR 5/8 Yellowish red
42	1, 2, 3, 4			Clay, soft, same as above	5YR 5/8 Yellowish red
44	2, 4, 4, 5			Clay, soft to medium, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Quillen Date 04/14/89 Page 3 of 3

Hole No. 4 Sample Interval ____ Total depth 50.2 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	1, 2, 4, 4			Clay, soft, same as above with fine well sorted sand @ 45.8'	5YR 5/8 Yellowish red
48	2, 2, 5, 6			Clay, very plastic, soft to medium, larger amounts of weathered shale and chert	5YR 5/8 Yellowish red
50	2, 4, 6, 7			Clay, plastic, soft to medium, some sand and a layer of chert fragments @ 49.6'	5YR 5/8 Yellowish red
52	2, 7, 10			Clay, soft to hard, refusal material chert @ 50.2'	5YR 5/8 Yellowish red
54					
56					
58					
60					
62					
64					
66					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/06/89 Page 1 of 2

Hole No. 5 Sample Interval _____ Total depth 31.8 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070 - A Data Verified By _____ Date Verified _____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 2, 2, 2			Clay, plastic, soft, with humus	5YR 4/6 Yellowish red
4	2, 2, 1, 1			Clay, plastic, soft, chert fragments and some sand	5YR 4/6 Yellowish red
6	1, 2, 4, 4			Clay, plastic, soft, same as above	5YR 4/6 Yellowish red
8	2, 2, 2, 3			Clay, plastic, soft, mixed limy chert fragments	5YR 4/6 Yellowish red
10	4, 6, 4, 4			Clay, same as above, soft to medium	5YR 4/6 Yellowish red
12	5, 6, 4, 8			Clay, same as above	5YR 4/6 Yellowish red
14	6, 17, 21, 35			Clay, plastic, medium to hard, large chert fragments	5YR 4/6 Yellowish red
16	10, 10, 7, 10			Clay, same as above, medium to stiff	5YR 4/4 Reddish brown
18	2, 4, 7, 7			Clay, same as above, soft to medium	5YR 4/4 Reddish brown
20	4, 5, 7, 8			Clay, very plastic, medium,very saturated, chert fragments with organic streaking	5YR 4/4 Reddish brown
22	5, 6, 6, 7			Clay, same as above	5YR 4/4 Reddish brown

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/06/89 Page 2 of 2

Hole No. 5 Sample Interval ____ Total depth 31.8 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070 - A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	4, 6, 6, 7			Clay, same as above with more organic streaking	5YR 4/4 Reddish brown
26	2, 5, 5, 7			Clay, soft to medium, same as above	5YR 4/4 Reddish brown
28	2, 3, 2, 3			Clay, soft, same as above	5YR 4/4 Reddish brown
30	2, 3, 4, 4			Clay, soft, same as above, with large amounts of chert fragments	5YR 4/4 Reddish brown
32	4, 10, 15, 10			Clay, medium to hard, refusal material chert @ 31.8'	5YR 4/4 Reddish brown
34					
36					
38					
40					
42					
44					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 02/02/89 Page 1 of 3
Hole No. 6 Sample Interval ____ Total depth 47.3 Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070 - A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 5, 8, 6			Clay, soft to medium, - 6" humus layer, mixed detritus	5YR 3/4 Dark reddish brown
4	2, 3, 6, 8			Clay, plastic, soft to medium, white chert fragments	5YR 4/6 Yellowish red
6	5, 7, 9, 7			Clay, medium to stiff, same as above	5YR 4/6 Yellowish red
8	7, 3, 4, 7			Clay, plastic, soft to medium, with large amounts of mixed chert fragments	5YR 3/3 Dark reddish brown
10	2, 4, 5, 6			Clay, same as above	5YR 4/6 Yellowish red
12	3, 3, 4, 5			Clay, same as above	5YR 4/6 Yellowish red
14	7, 15, 15, 16			Clay, plastic, medium to very stiff, organic streaking with chert fragments	5YR 4/6 Yellowish red
16	6, 6, 7, 10			Clay plastic, medium to stiff, small amounts of well sorted sand with chert fragments	5YR 4/6 Yellowish red
18	2, 3, 6, 10			Clay, same as above	5YR 5/8 Yellowish red
20				Clay, same as above	5YR 5/8 Yellowish red
22				Clay, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 02/02/89 Page 2 of 3

Hole No. 6 Sample Interval ____ Total depth 47.3 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070 - A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24				Clay, same as above	5YR 5/8 Yellowish red
26				Clay, very plastic, small amounts of sand and chert	5YR 5/8 Yellowish red
28	2, 3, 5, 5			Clay, plastic, soft to medium, damp, organic streaking, chert fragments and - 10% well sorted sand	5YR 5/8 Yellowish red
30	2, 2, 3, 4			Clay, same as above	5YR 5/8 Yellowish red
32	2, 2, 3, 5			Clay, same as above	5YR 5/8 Yellowish red
34	2, 2, 2, 4			Clay, same as above	5YR 5/8 Yellowish red
36	2, 2, 3, 4			Clay, soft, damp with organic streaking and mixed chert fragments	5YR 5/8 Yellowish red
38	1, 2, 2, 3			Clay, same as above	5YR 5/6 Yellowish red
40	1, 1, 3, 4			Clay, same as above	5YR 5/6 Yellowish red
42				Clay, same as above	5YR 5/6 Yellowish red
44	2, 3, 5, 7			Clay, medium to very stiff, large amounts of mixed chert fragments	5YR 5/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 02/02/89 Page 3 of 3

Hole No. 6 Sample Interval ____ Total depth 47.3 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070 - A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	5 7 12 17			Clay, medium to hard, refusal material was chert @ 47.3'	5YR 5/6 Yellowish red
48	5 7 15/3				
50					
52					
54					
56					
58					
60					
62					
64					
66					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/01/89 Page 1 of 1
Hole No. 7 Sample Interval ______ Total depth 6.7' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	3, 3, 2, 2			Clay, plastic, soft, with mixed cherty dolostone	5YR 5/6 Yellowish red
4	3, 10, 15, 20			Clay, plastic, soft to very stiff, with mixed limestone and chert fragments	5YR 5/8 Yellowish red
6	6, 11, 25/.3			Clay, plastic, medium to hard, with mixed limestone and chert fragments, refusal @ 5.3'	5YR 5/8 Yellowish red
8	10, 25/.2			Clay, with chert refusal Offset, augered to 6', sample refusal material was chert @ 6.7'	5YR 3/4 Dark reddish brown
10					
12					
14					
16					
18					
20					
22					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/29/89 Page 1 of 2

Hole No. 8 Sample Interval ____ Total depth 24.9' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
	5			Clay, plastic, soft to medium, mixed chert with organic streaking	5YR 5/8 Yellowish red
	3				
	3				
2	3				
	2			Clay, plastic, soft to stiff, mixed chert with small amounts of organic streaking, silty clay	5YR 5/8 Yellowish red
	4				
	6				
4	9				
	7			Clay, plastic, medium to very stiff, damp @ 4.5', olive green layer of highly weathered shale, minor organics @ 5.0'	5YR 5/8 Yellowish red
	12				
	15				
6	20				
	8			Clay, plastic, medium to very stiff, mixed with pulverized dolostone fragments	5YR 5/8 Yellowish red
	9				
	12				
8	15				
	6			Clay, plastic, medium to very stiff, mixed with chert fragments, organic streaking, and olive yellow staining	5YR 5/8 Yellowish red
	9				
	12				
10	16				
	7			Clay, plastic, medium to stiff, highly weathered yellow shale within clay matrix	5YR 5/8 Yellowish red
	12				
	13				
12	13				
	5			Clay, same as above	5YR 5/8 Yellowish red
	6				
	8				
14	10				
	3			Clay, soft to medium, silty clay intermixed with highly weathered shale	5YR 6/8 Reddish yellow
	3				
	4				
16	5				
	2			Clay, soft to stiff, chert layer @ 17.5', some well sorted sand	5YR 6/8 Reddish yellow
	5				
	13				
18	6				
	5			Clay, medium, with mixed chert fragments, saturated zone ~ 20.0'	5YR 6/8 Reddish yellow
	6				
	5				
20	5				
	2			Clay, very plastic, soft to medium, some organics with weathered olive shale	5YR 5/8 Yellowish red
	4				
	4				
22	6				

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/29/89 Page 2 of 2

Hole No. 8 Sample Interval ______ Total depth 24.9' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	5 8 13 14			Clay, very plastic, medium to stiff, chert layer @ 23.5', very thin organic layer	5YR 5/8 Yellowish red
26	20/.4			Clay, hard, refusal material chert @ 24.9'	5YR 5/8 Yellowish red
28					
30					
32					
34					
36					
38					
40					
42					
44					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 01/31/89 Page 1 of 2

Hole No. 11A Sample Interval ______ Total depth 37.3' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	4 5 6 4			Clay, soft to medium, with mixed limestone fragments	5YR 4/4 Reddish brown
4	1 3 2 2			Clay, very plastic, soft	5YR 4/6 Yellowish red
6	2 3 4 5			Clay, very plastic, soft to medium	5YR 4/6 Yellowish red
8	3 4 4 5			Clay, very plastic, soft to medium	5YR 4/6 Yellowish red
10	3 4 5 5			Clay, very plastic, soft to medium, organic streaking	5YR 3/4 Dark reddish brown
12	2 3 4 5			Clay, very plastic, soft to medium, organic streaks with bits of chert fragments	5YR 4/6 Yellowish red
14	2 3 3 4			Clay, very plastic, soft, organic streaks with bits of chert fragments	5YR 4/6 Yellowish red
16	2 5 10 9			Clay, very plastic, soft to stiff, large amounts of mixed chert fragments predominating @ 15.5'	5YR 4/6 Yellowish red
18	3 2 3 4			Clay, very plastic, soft, large amounts of mixed chert and limestone fragments	5YR 4/6 Yellowish red
20	3 4 3 4			Clay, very plastic, soft, mixed chert and dolomite fragments	5YR 4/6 Yellowish red
22	3 7 22 12			Clay, very plastic, soft to very stiff, mixed chert and dolomite fragments, wet	5YR 4/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 01/31/89 Page 2 of 2

Hole No. 11A Sample Interval ____ Total depth 37.3' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	5, 7, 8, 11			Clay, very plastic, medium to stiff, damp, mixed chert, calcite, and dolomite fragments	5YR 4/6 Yellowish red
26	5, 5, 7, 8			Clay, very plastic, medium, mixed chert fragments	5YR 4/6 Yellowish red
28	2, 3, 5, 5			Clay, very plastic, soft to medium, mixed chert fragments	5YR 4/6 Yellowish red
30	1, 2, 3, 4			Clay, very plastic, soft, mixed chert fragments	5YR 4/6 Yellowish red
32	1, 2, 2, 3			Clay, same as above	5YR 4/6 Yellowish red
34	2, 2, 3, 4			Clay, same as above	5YR 5/6 Yellowish red
36	2, 3, 4, 5			Clay, very plastic, soft to medium, very wet	5YR 5/6 Yellowish red
38	7, 8, 15/.3			Clay, with refusal material dolostone @ 37.3'	5YR 5/6 Yellowish red
40					
42					
44					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C Landguth Date 02/01/89 Page 1 of 2

Hole No. 11B Sample Interval ______ Total depth 42.3' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	4 10 5 3			Clay, soft to stiff, with blue stone gravel fill	5YR 3/3 Dark reddish brown
4	1 2 1 1			Clay, very plastic, soft, with some mixed chert	5YR 4/6 Yellowish red
6	1 3 4 5			Clay, very plastic, soft to medium, with some mixed chert	5YR 4/6 Yellowish red
8	4 6 5 7			Clay, very plastic, medium, with some mixed chert	5YR 4/6 Yellowish red
10	3 4 4 6			Clay, very plastic, medium, with some mixed chert	5YR 3/4 Dark reddish brown
12	3 3 4 5			Clay, very plastic, soft to medium, with some organic streaking	5YR 3/4 Dark reddish brown
14	2 2 3 5			Clay, very plastic, soft to medium	5YR 4/6 Yellowish red
16	3 4 4 5			Clay, very plastic, soft to medium, some chert fragments and organic streaks	5YR 5/8 Yellowish red
18	2 3 4 4			Clay, same as above	5YR 5/8 Yellowish red
20	2 3 4 6			Clay, very plastic, soft to medium, with intermixed chert fragments and sand	5YR 4/6 Yellowish red
22	3 4 7 6			Clay, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C Landguth Date 02/01/89 Page 2 of 2

Hole No. 11B Sample Interval ____ Total depth 42.3' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	5, 7, 11, 10			Clay, medium to stiff, large amounts of chert fragments, saturated	5YR 4/6 Yellowish red
26	5, 3, 5, 9			Clay, plastic, soft to stiff, large amounts of mixed chert	5YR 4/6 Yellowish red
28	3, 3, 4, 4			Clay, very plastic, soft, large chert fragments	5YR 4/6 Yellowish red
30	3, 4, 4, 5			Clay, very plastic, soft to medium, chert fragments	5YR 4/6 Yellowish red
32	2, 3, 3, 5			Clay, very plastic, soft to medium, chert fragments	5YR 5/6 Yellowish red
34	2, 3, 4, 5			Clay, same as above	5YR 5/8 Yellowish red
36	7, 10, 12, 15			Clay, very plastic, medium to very stiff, chert fragments	5YR 5/8 Yellowish red
38	6, 6, 6, 6			Lost sample	
40	2, 6, 12, 23			Clay, soft to very stiff, mixed chert with well rounded and sorted sand	5YR 5/8 Yellowish red
42	9, 11, 10, 15/.1			Clay, very plastic, stiff to hard, refusal material chert @ 42.3'	5YR 5/8 Yellowish red
44					

BOREHOLE SUMMARY INFORMATION

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Prepared By J.L. Zutman Date 01/19/89 Page 1 of 2

Hole No. 12A Sample Interval ________ Total depth 41.2' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ________ Date Verified ________

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	3, 5, 5, 5			Clay, plastic, soft to medium, damp, with small chert fragments brown	5YR 3/4 Dark reddish
4	1, 1, 2, 3			Clay, very plastic, very soft, moist	5YR 4/4 Reddish brown
6	2, 3, 4, 5			Clay, very plastic, soft to medium, some black organic streaks, minor amounts of sand	5YR 4/6 Yellowish red
8	2, 3, 3, 3			Clay, plastic, soft, organic streaks, minor amounts of fine to medium well rounded sand, a few sand pebbles, minor amounts of silt	5YR 4/6 Yellowish red
10	4, 4, 7, 10			Clay, plastic, medium to stiff, large piece of limestone near top of section, numerous chert and limestone fragments, organic streaks, ~ 10% sand	5YR 5/6 Yellowish red
12	4, 5, 5, 4			Clay, plastic, medium, numerous chert fragments, organic staining, ~ 10% fine grained sand	5YR 4/6 Yellowish red
14	2, 3, 3, 3			Clay, soft, sandy, very wet, fine to medium grained sand with sand pebbles, organic staining	5YR 5/6 Yellowish red
16	2, 2, 3, 3			Clay, very plastic, soft, very wet, minor amounts of chert and organic chips	5YR 5/6 Yellowish red
18	2, 3, 3, 4			Clay, very plastic, soft, very wet, sandy clay, a few small chert fragments	5YR 4/6 Yellowish red
20	4, 5, 7, 10			Clay, very plastic, medium to stiff, sandy clay, a few organic chips, minor amounts of chert	5YR 4/6 Yellowish red
22	4, 5, 7, 7			Clay, very plastic, medium, silty, sandy, clay with numerous well rounded organic stained pebbles, very wet	5YR 4/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

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Prepared By J.L. Zutman Date 01/19/89 Page 2 of 2

Hole No. 12A Sample Interval ______ Total depth 41.2' Sample Type 2" X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	3, 5, 7, 8			Clay, very plastic, soft to stiff, numerous chert fragments, organically stained pebbles, very wet	5YR 4/6 Yellowish red
26	2, 3, 5, 5			Clay, very plastic, soft to medium, larger chert fragments with some organic staining, very wet	5YR 4/6 Yellowish red
28	2, 3, 4, 4			Clay, soft to medium, same as above with increasing % of shaly particles, damp	5YR 4/6 Yellowish red
30	2, 3, 4, 4			Clay, same as above, moist	5YR 4/6 Yellowish red
32	2, 3, 3, 5			Clay, soft to medium, numerous chert fragments to 1/2", moist increasing to wet	5YR 4/6 Yellowish red
34	1, 2, 4, 7			Clay, plastic, soft, numerous chert fragments	5YR 4/6 Yellowish red
36	2, 3, 4, 11			Clay, soft to stiff, same as above	5YR 4/6 Yellowish red
38	3, 8, 7, 10			Clay, soft to stiff, dolomite and chert fragments	5YR 4/6 Yellowish red
40	3, 5, 6, 7			Clay, soft to medium, very soupy, chert with carbonaceous and non-carbonaceous fragments	5YR 4/6 Yellowish red
42	6, 13, 10/.2			Clay, same as above, refusal @ 41.2'	5YR 4/6 Yellowish red
44					

BOREHOLE SUMMARY INFORMATION

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Hole No. 13A Sample Interval ______ Total depth 12.2' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	3 4 5 3			Clay, soft to medium, sand and silt, numerous rock fragments	10YR 4/3 Brown
4	1 1 1 3			Sandy clay, soft, moist, low plasticity	10YR 4/3 Brown
6	3 4 5 4			No sample	
8	2 4 6 6			Sandy clay grading to clay @ 6.5', soft to medium, mottled yellow clay also	5YR 4/6 Yellowish red
10	5 8 12 9			Clay, medium to very stiff, with mixed chert fragments	5YR 4/6 Yellowish red
12	5 6 9 8			Clay, grading to sandy clay, medium to stiff, numerous chert fragments with dolomite at end of section	5YR 4/6 Yellowish red
14	25/.2			Massive chert, sample and auger refusal @ 12.2'	
16					
18					
20					
22					

BOREHOLE SUMMARY INFORMATION

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Prepared By D.C. Landguth Date 04/10/89 Page 1 of 1
Hole No. 13B Sample Interval ________ Total depth 11.2' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070-A Data Verified By ____________ Date Verified ________

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	3, 4, 7, 3			Sandy clay, soft to medium, mixed chert fragments	5YR 3/4 Dark reddish brown
4	2, 2, 3, 4			Sandy clay, soft, same as above	5YR 3/4 Dark reddish brown
6	2, 4, 4, 5			Clay, plastic, soft to medium, mixed chert fragments	5YR 5/6 Yellowish red
8	3, 5, 8, 12			Clay, plastic, medium to very stiff, lots of mixed chert fragments	5YR 5/6 Yellowish red
10	25, 12, 12, 6			Clay, plastic, medium to very stiff, lots of mixed chert fragments	5YR 5/6 Yellowish red
12	10, 15, 17, 11/.3			Clay, predominantly mixed chert fragments, sample refusal @ 11.2'	5YR 5/6 Yellowish red
14					
16					
18					
20					
22					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth   Date 02/22/89   Page 1 of 1

Hole No. 14   Sample Interval ______   Total depth 19.8   Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates   Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A   Data Verified By ______   Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 4, 4, 5			Clay, plastic, soft to medium, mixed with humus	5YR 3/4 Dark reddish brown
4	4, 2, 3, 2			Clay, plastic, soft, large fragments of mixed chert	5YR 3/4 Dark reddish brown
6	2, 2, 2, 3			Clay, plastic, soft, with mixed chert and well sorted sand	5YR 4/6 Yellowish red
8	2, 2, 4, 2			Clay, same as above	5YR 4/6 Yellowish red
10	3, 4, 3, 2			Clay, plastic, soft, with mixed dolostone and chert fragments, organic streaks	5YR 4/4 Reddish brown
12	3, 4, 5, 3			Clay, plastic, soft to medium, with mixed chert and dolostone fragments, minor amounts of sand	5YR 4/4 Reddish brown
14	4, 5, 8, 10			Clay, plastic, medium to stiff, same as above	5YR 4/4 Reddish brown
16	4, 6, 8, 5			Clay, plastic, medium, same as above	5YR 4/6 Yellowish red
18	4, 6, 8, 5			Clay, plastic, medium, larger chert fragments with dolostone	5YR 4/6 Yellowish red
20				Clay, hard, same as above with refusal @ 19.8', refusal material chert	5YR 4/6 Yellowish red
22					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

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Hole No. 17A Sample Interval ______ Total depth 45.9' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	5, 6, 5, 4			Clay, plastic, medium, minor amounts of sand and chert fragments	5YR 4/6 Yellowish red
4	2, 3, 4, 6			Clay, very plastic, soft to medium	5YR 4/6 Yellowish red
6	3, 6, 6, 7			Clay, same as above	5YR 4/6 Yellowish red
8	3, 5, 4, 4			Clay, same as above	5YR 4/6 Yellowish red
10	2, 2, 3, 2			Clay, very plastic, soft, minor amounts of mixed chert	5YR 4/6 Yellowish red
12	3, 3, 3, 4			Clay, very plastic, soft, same as above with white chert	5YR 4/6 Yellowish red
14	2, 2, 3, 4			Clay, same as above, sample is damp	5YR 4/6 Yellowish red
16	2, 2, 3, 4			Clay, same as above with more and larger fragments of mixed chert	5YR 5/8 Yellowish red
18	2, 2, 3, 4			Clay, same as above	5YR 5/8 Yellowish red
20	3, 4, 7, 4			Clay, soft to medium, with minor amounts of mixed chert and sand	5YR 5/8 Yellowish red
22	3, 4, 2, 4			Clay, soft, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/02/89 Page 2 of 3

Hole No. 17A Sample Interval ________ Total depth 45.9' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ________ Date Verified ________

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	4, 5, 4, 7			Clay, same as above, sample saturated	5YR 5/8 Yellowish red
26				Clay, very wet, with intermixed fine grained well sorted sand	5YR 5/8 Yellowish red
28	7, 15, 13, 12			Clay, plastic, medium to very stiff, silty, large fragments of chert with organic staining	5YR 4/6 Yellowish red
30	3, 7, 7, 8			Clay, soft to medium, with silt, mixed fragments of grey-white chert	5YR 4/6 Yellowish red
32	4, 12, 15, 16			Clay, medium to very stiff, silt, and poorly sorted sand	5YR 4/6 Yellowish red
34	16, 12, 10, 16			Clay, stiff to very stiff, silt, poorly sorted sand with large chert fragments	5YR 5/8 Yellowish red
36	9, 9, 9, 10			Clay, medium, silt, poorly sorted sand, chert fragments and dark red sandstone	5YR 5/8 Yellowish red
38	6, 8, 10, 12			Clay, medium	5YR 5/8 Yellowish red
40	8, 10, 11, 14			Clay, same as above	5YR 5/8 Yellowish red
42	4, 10, 12, 14			Clay, plastic, medium to stiff	5YR 5/8 Yellowish red
44	5, 8, 10, 11			Clay, plastic, medium to stiff, mixed with silt and small chert fragments	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth Date 03/02/89 Page 3 of 3
Hole No. 17A Sample Interval Total depth 45.9' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070-A Data Verified By Date Verified

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	4 7 9 15/.3			Clay, medium to hard, same as above, with organic streaking, sample refusal material chert @ 45.9'	5YR 5/8 Yellowish red
48					
50					
52					
54					
56					
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BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. QUILLEN Date 04/13/89 Page 1 of 2

Hole No. 17B Sample Interval ____ Total depth 42.2' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	5, 6, 5, 6			Clay, plastic, medium, organic material with limestone fragments	5YR 4/6 Yellowish red
4	3, 5, 6, 7			Clay, plastic, soft to medium, organic streaking with dolomitic fragments	5YR 5/8 Yellowish red
6	8, 9, 13, 12			Clay, very plastic, organic streaking with a reddish yellow clay layer @ 5.0'(5YR 7/8)	5YR 5/8 Yellowish red
8	4, 5, 6, 5			Clay, very plastic, medium, with minor dolostone fragments	5YR 5/8 Yellowish red
10	2, 4, 4, 4			Clay, soft, same as above	5YR 5/8 Yellowish red
12	2, 3, 3, 4			Clay, same as above, saturated zone @ 11.0'	5YR 5/8 Yellowish red
14	2, 3, 3, 4			Clay, same as above, very moist	5YR 5/8 Yellowish red
16	1, 2, 3, 3			Clay, same as above	5YR 5/8 Yellowish red
18	2, 2, 3, 6			Clay, soft to medium, same as above	5YR 5/8 Yellowish red
20	3, 4, 4, 4			Clay, soft, sandy, silty, very moist, dolostone fragments	5YR 5/8 Yellowish red
22	2, 3, 4, 4			Clay, soft, well sorted sand, silty, very moist	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

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Prepared By J. L. QUILLEN Date 04/13/89 Page 2 of 2
Hole No. 17B Sample Interval ______ Total depth 42.2' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All' Terrain Drill Rig
Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	1, 1, 4, 4			Clay, same as above	5YR 5/8 Yellowish red
26	1, 1, 2, 3			Clay, soft, very plastic, saturated, silty, small dolostone fragments, organic streaking	5YR 5/8 Yellowish red
28	3, 2, 6, 3			Clay, soft to medium, same as above	5YR 5/8 Yellowish red
30	3, 2, 3, 2			Clay, soft, same as above	5YR 5/8 Yellowish red
32	6, 8, 8, 10			Clay, medium, saturated, chert fragments @ 32.0'	5YR 5/8 Yellowish red
34	3, 6, 4, 4			Clay, soft to medium, chert and sand fragments, saturated, organic layers	5YR 5/8 Yellowish red
36	2, 3, 2, 4			Clay, soft, shaly, cherty, sandy, very wet sample	5YR 5/8 Yellowish red
38	4, 5, 4, 6			Clay, soft to medium, large amounts of weathered shale, mixed chert fragments, organic streaking	5YR 5/8 Yellowish red
40	4, 7, 13, 16			Clay, medium to very stiff, very plastic, layers of weathered shale, chert fragments form 38.0 to 39.0'	5YR 5/8 Yellowish red
42	4, 6, 7, 8			Clay, medium, same as above	5YR 5/8 Yellowish red
44	10/.2			Clay, hard, sample refusal material chert @ 42.2', weathered shale also	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J.L. ZUTMAN Date______ Page 1 of 2
Hole No. 18 Sample Interval______ Total depth 30.5 Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All' Terrain Drill Rig
Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	4 5 6 7			Clay, medium, minor amounts of silt, a few fragments of chert, moist	5YR 4/4 Reddish brown
4	1 1 1 1			Clay, soft, same as above	5YR 4/4 Reddish brown
6	1 1 1 2			Clay, very soft, plastic, abundance of chert fragments, moist	5YR 4/4 Reddish brown
8	2 2 3 3			Clay, soft, same as above, some medium grained sub-rounded sand	5YR 4/4 Reddish brown
10	3 5 4 6			Clay, soft to medium, same as above, a sand lens @ 9.3', very wet	5YR 4/4 Reddish brown
12	2 2 3 3			Clay, soft, large 1" limestone fragments @ 10.5', large chert fragments @ 11.0', some secondary calcite, moist	5YR 4/4 Reddish brown
14	2 2 3 3			Clay, soft, abundant dolomite fragments, moist	5YR 4/4 Reddish brown
16	3 3 5 5			Clay, soft to medium, very wet, @ 14.0 to 15.4' very plastic, grading to medium, very fractured dolomite @ 15.8'	5YR 4/4 Reddish brown
18	2 4 4 5			Clay, soft to medium, very wet to moist, fragments of chert and dolomite	5YR 4/4 Reddish brown
20	1 2 2 3			Clay, very soft to soft, same as above with alternating blueish green beds	5YR 4/4 Reddish brown
22	3 3 4 4			Clay, soft, same as above with mottled dolomitic rock fragments	5YR 4/4 Reddish brown

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J.L. ZUTMAN Date_____ Page 2 of 2
Hole No. 18 Sample Interval_____ Total depth 30.5 Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All' Terrain Drill Rig
Project K-1070- A Data Verified By _____ Date Verified_____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	2, 2, 2, 4			Clay, same as above	5YR 4/4 Reddish brown
26	2, 11, 17, 8			Clay, soft to very stiff, some rock fragments	5YR 4/4 Reddish brown
28	1, 2, 3, 4			Clay, very soft to soft, same as above, with blueish green clay @ 27.0'	5YR 4/4 Reddish brown
30	1, 3, 4, 2			Clay, same as above, thin lens of organic material (1/8") @ 29.0'	5YR 4/4 Reddish brown
32	10/.5			Limestone, hard, with some chert fragments in the sampling spoon, refusal @ 30.5'	
34					
36					
38					
40					
42					
44					

BOREHOLE SUMMARY INFORMATION

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Prepared By D.C. LANDGUTH Date 4/10/89 Page 1 of 1

Hole No. 19A Sample Interval ______ Total depth 21.4' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	1, 2, 1, 1			Clay, plastic, very soft to soft, with mixed chert	5YR 4/6 Yellowish red
4	9, 8, 6, 7			Clay, plastic, medium to stiff, large chert fragments, with minor organics	5YR 5/6 Yellowish red
6	7, 11, 9, 12			Clay, same as above	5YR 5/6 Yellowish red
8	5, 7, 12, 16			Clay, plastic, medium to very stiff, with some chert fragments	5YR 5/6 Yellowish red
10	7, 12, 12, 16			Clay, plastic, medium to very stiff, with intermixed chert fragments	5YR 5/6 Yellowish red
12	7, 11, 13, 12			Clay, plastic, medium to stiff, mixed sand and chert fragments, sand is poorly sorted	5YR 5/8 Yellowish red
14	4, 6, 13, 15			Clay, plastic, soft to stiff, with minor streaks of organics	5YR 5/8 Yellowish red
16	9, 14, 15, 21			Clay, plastic, medium to very stiff, with mixed chert and minor organic streaks	5YR 5/8 Yellowish red
18	3, 4, 5, 6			Clay, plastic, soft to medium, large amounts of organics, wet @ 17'	5YR 5/8 Yellowish red
20	4, 4, 7, 8			Clay, medium, with mixed chert from 18.0' to 18.5', shaly layers starting @ 19.1', shale is pale yellow to olive green	5YR 5/8 Yellowish red
22	5, 19, 17			Shaly clay, medium to hard, cross bedding of shale @ 20.5', refusal material chert @ 21.4'	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C Landguth Date 03/07/89 Page 1 of 2

Hole No. 20 Sample Interval ______ Total depth 43.7' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 3, 4, 4			Clay, plastic, soft	5YR 5/6 Yellowish red
4	2, 4, 6, 10			Clay, plastic, soft to stiff, minor amounts of chert fragments	5YR 5/8 Yellowish red
6	4, 6, 8, 11			Clay, plastic, medium to stiff, with mixed limy chert fragments	5YR 5/8 Yellowish red
8	4, 5, 8, 9			Clay, plastic, medium to stiff, with large amounts of white chert fragments @ 8.0', organic streaking with limy chert	5YR 5/8 Yellowish red
10	6, 10, 10, 14			Clay, plastic, medium to stiff, large white chert fragments	5YR 5/8 Yellowish red
12	8, 11, 21, 15			Clay, plastic, medium to very stiff, from 11.0 to 12.0' massive quantities of crushed and fragmented chert	5YR 5/8 Yellowish red
14	8, 11, 13, 15			Clay, plastic, medium, same as above	5YR 5/8 Yellowish red
16	10, 14, 17, 14			Clay, plastic, stiff, mixed chert fragments with organic streaking, some limonite	5YR 5/8 Yellowish red
18	8, 10, 12, 10			Clay, plastic, stiff, with limy chert	5YR 5/8 Yellowish red
20	8, 10, 12, 12			Clay, plastic, stiff, with limy chert	5YR 5/8 Yellowish red
22	4, 4, 4, 7			Clay, soft to medium, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C Landguth Date 03/07/89 Page 2 of 2

Hole No. 20 Sample Interval_____ Total depth 43.7' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By _____ Date Verified _____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	4, 5, 4, 12			Clay, medium to stiff, same as above	5YR 5/8 Yellowish red
26	4, 4, 7, 7			Clay, medium, with small bands of limy chert	5YR 5/8 Yellowish red
28	2, 3, 3, 5			Clay, plastic, soft to medium	5YR 5/8 Yellowish red
30	3, 4, 4, 5			Clay, same as above	5YR 5/8 Yellowish red
32	3, 5, 6, 9			Clay, same as above	5YR 5/8 Yellowish red
34	2, 5, 5, 9			Clay, very plastic, soft to stiff, mixed chert with minor amounts of silt and sand	5YR 5/8 Yellowish red
36	2, 3, 4, 5			Clay, medium, with shale appearing @ 35.0'	5YR 5/8 Yellowish red
38	1, 2, 4, 4			Clay, very soft to medium, with thin lenses of shale	5YR 5/6 Yellowish red
40	2, 3, 5, 8			Clay, soft to medium, with mixed limy chert, intermixed with poorly sorted sand	5YR 5/6 Yellowish red
42	3, 5, 5, 7			Clay, soft to medium, with some small amounts of mixed chert	5YR 5/6 Yellowish red
44	4, 7, 7, 10/.3			Clay, medium to hard, with mixed limy chert, sample refusal material chert @ 43,7'	5YR 5/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

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Hole No. 21 Sample Interval ____ Total depth 42.1' Sample Type 2" X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070-A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	4, 6, 6, 6			Clay, medium, with sand and silt, numerous rock fragments	5YR 4/4 Reddish brown
4	4, 5, 6, 3			Clay, medium, with lesser amounts of sand and silt, some carbonaceous material scattered, moist	5YR 4/4 Reddish brown
6	4, 6, 6, 8			Clay, plastic, medium, minor sands and silts	2.5YR 3/6 Dark red
8	3, 4, 4, 4			Clay, plastic, medium, with many rock fragments	2.5 YR 3/6 Dark red
10	3, 4, 4, 3			Clay, soft, with assorted dolomite fragments scattered throughout, damp to moist	2.5 YR 3/6 Dark red
12	6, 5, 5, 6			Clay, medium, same as above	2.5 YR 3/6 Dark red
14	3, 4, 4, 4			Clay, soft, some sand and silt	2.5 YR 3/6 Dark red
16	3, 4, 5, 5			Clay, medium, same as above with rock fragments and carbonaceous fragments	2.5 YR 3/6 Dark red
18	2, 4, 4, 5			Clay, plastic, same as above	2.5 YR 4/6 Red
20	3, 4, 4, 6			Clay, plastic, same as above	2.5 YR 4/6 Red
22	5, 9, 17, 22			Clay, medium to very stiff, wet, dolomite and chert fragments	2.5 YR 4/6 Red

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Hole No. 21 Sample Interval ______ Total depth 42.1' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	12, 8, 11, 12			Clay, stiff, same as above with large chert fragments	2.5 YR 4/6 Red
26	5, 7, 8, 10			Clay, medium, very plastic, sticky, moist	2.5 YR 4/6 Red
28	3, 4, 6, 8			Clay, soft to medium, sticky, mottled from 27.5' to 28.0'	2.5 YR 4/6 Red
30	4, 7, 12, 14			Clay, same as at [illegible]	2.5 YR 4/6 Red
32	8, 11, 20, 21			Clay, medium to very stiff	2.5 YR 4/6 Red
34	7, 11, 8, 7			Clay, silt, medium to stiff, alternating yellow and black banding in some places	2.5 YR 4/6 Red
36	8, 9, 15, 17			Clay, medium	5YR 4/4 Reddish brown
38	3, 8, 11, 10			Clay, same as above	5YR 4/4 Reddish brown
40	2, 4, 6, 7			Clay, same as above	5YR 4/4 Reddish brown
42	7, 9, 15/.3			Clay, mottled with rock fragments in shoe, sample refusal @ 42.1'	5YR 4/4 Reddish brown
44					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D. C. Landguth Date 03/30/89 Page 1 of 3

Hole No. 22 Sample Interval ______ Total depth 54.3 Sample Type 2" X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	2, 3, 3, 5			Clay, plastic, soft to medium, minor amounts of fine sand and chert	5YR 4/6 Yellowish red
4	2, 3, 5, 7			Clay, same as above with organic streaking and larger amounts of chert	5YR 5/8 Yellowish red
6	5, 5, 5, 6			Clay, medium, same as above	5YR 4/4 Reddish brown
8	3, 3, 3, 5			Clay, soft to medium, same as above	5YR 4/4 Reddish brown
10	2, 4, 4, 4			Clay, soft, same as above	5YR 4/4 Reddish brown
12	2, 3, 4, 4			Clay, plastic, soft, mixed chert fragments and some organic streaking	5YR 5/8 Yellowish red
14	2, 3, 3, 4			Clay, same as above with larger amounts of mixed chert	5YR 5/8 Yellowish red
16	2, 2, 3, 4			Clay, same as above	5YR 5/8 Yellowish red
18	3, 3, 4, 2			Clay, plastic, soft, with mixed chert	5YR 5/8 Yellowish red
20	3, 3, 4, 4			Clay, plastic, soft, mixed chert with minor organic streaking, saturated zone @ 18.0'	5YR 5/8 Yellowish red
22	2, 2, 2, 3			Clay, plastic, soft, silty, with mixed chert	5YR 5/8 Yellowish red

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Hole No. 22 Sample Interval ______ Total depth 54.3 Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	3, 12, 12			Clay, plastic, hard, chert at end of shoe	5YR 5/8 Yellowish red
26				Augered past chert obstruction	
28	5, 8, 13, 10			Clay, medium	5YR 5/8 Yellowish red
30	2, 9, 8, 9			Clay, plastic, mixed chert fragments, very wet	5YR 5/8 Yellowish red
32	3, 3, 3, 4			Clay, very wet	5YR 3/4 Dark reddish brown
34	2, 2, 2, 6			Clay, same as above	5YR 3/4 Dark reddish brown
36	1, 2, 2, 3			Clay, soft to medium, plastic, small chert fragments with organic streaking, highly weathered shale	5YR 5/6 Yellowish red
38	2, 3, 3, 4			Clay, very plastic, same as above	5YR 5/6 Yellowish red
40	3, 4, 5, 5			Clay, soft, layers of weathered shale, chert and organic layers	5YR 5/6 Yellowish red
42	2, 3, 4, 6			Clay, soft to medium, well sorted sandy layers with porous sandstone	5YR 5/6 Yellowish red
44	2, 3, 2, 3			Clay, soft to medium, same as above with iron staining	5YR 5/6 Yellowish red

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Hole No. 22 Sample Interval ______ Total depth 54.3 Sample Type 2" X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	2 3 4 5			Clay, plastic, soft, with intermixed sand, small amounts of organics, dolostone	5YR 6/8 Reddish yellow
48	6 7 5 4			Clay, same as above	5YR 6/8 Reddish yellow
50	4 6 7 12			Clay, medium, same as above with small amounts of chert fragments	5YR 6/8 Reddish yellow
52	4 5 2 4			Clay, medium to stiff, chert fragments throughout	5YR 6/8 Reddish yellow
54	2 3 5 8			Clay, soft to medium, chert in shoe	5YR 6/8 Reddish yellow
56	15/0			Clay, soft to medium, plastic, mixed with chert, very wet Chert, sample refusal met, hard	5YR 6/8 Reddish yellow
58					
60					
62					
64					
66					

BOREHOLE SUMMARY INFORMATION

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Hole No. 23A   Sample Interval ______   Total depth 51.1'   Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates   Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A   Data Verified By ____________   Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	5 7 6 6			Clay, thin top-soil, medium, mixed limestone fragments	5YR 5/8 Yellowish red
4	3 4 6 7			Clay, plastic, medium, with minor organic streaking	5YR 5/8 Yellowish red
6	5 6 11 12			Clay, medium to stiff, iron staining with organic streaking, chert from 4.0 to 4.5'	5YR 5/8 Yellowish red
8	4 3 5 5			Clay, medium, sandy, cherty, and organic streaking	5YR 5/8 Yellowish red
10	4 5 6 6			Clay, medium, very plastic, cherty, intermixed with shale, moist	5YR 5/8 Yellowish red
12	6 5 5 5			Clay, same as above	5YR 5/8 Yellowish red
14	2 3 4 5			Clay, soft to medium, organic streaking with weathered shale	5YR 5/8 Yellowish red
16	2 3 3 4			Clay, soft, iron staining, minor organics	5YR 5/8 Yellowish red
18	2 2 3 4			Clay, soft, with chert, mixed organics	5YR 5/8 Yellowish red
20	5 5 6 7			Clay, medium, same as above, chert layer @ 19.0'	5YR 5/8 Yellowish red
22	3 4 4 6			Clay, soft to medium, very plastic, wet, chert, sandy, and small amounts of organics	5YR 6/8 Reddish yellow

BOREHOLE SUMMARY INFORMATION

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Prepared By D.C. Landguth / J.L. Quillen Date 04/05/89 Page 2 of 3
Hole No. 23A Sample Interval ______ Total depth 51.1' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070-A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	3, 3, 4, 4			Clay, soft, same as above	5YR 6/8 Reddish yellow
26	1, 4, 6, 6			Clay, very soft to medium, dolostone fragments, chert, and layers of weathered shale	5YR 6/8 Reddish yellow
28	2, 6, 13, 10			Clay, soft to medium, layer of chert @ 28.0', intermixed dolomite and chert	5YR 6/8 Reddish yellow
30	2, 6, 10, 13			Clay, soft to stiff, very plastic, small amounts of chert, organic streaking, weathered shale	5YR 5/8 Yellowish red
32	10, 7, 10, 14			Clay, medium to stiff, very plastic, small amounts of weathered shale, organic streaking throughout	5YR 5/8 Yellowish red
34	5, 7, 9, 13			Clay, medium to stiff, very plastic, organic layers, weathered shale	5YR 5/8 Yellowish red
36	4, 7, 9, 10			Clay, same as above	5YR 5/8 Yellowish red
38	5, 7, 9, 13			Clay, medium to stiff, very plastic, intermixed chert	5YR 5/8 Yellowish red
40	5, 7, 8, 10			Clay, medium to stiff, very plastic, organic layering, weathered shale	5YR 5/8 Yellowish red
42	3, 4, 5, 6			Clay, soft to medium, very plastic, weathered shale layers, lots of organics	5YR 5/8 Yellowish red
44	2, 3, 4, 17			Clay, soft to hard, same as above	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D.C. Landguth / J.L. Quillen Date 04/05/89 Page 3 of 3

Hole No. 23A Sample Interval ____ Total depth 51.1' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070-A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	2, 10, 12, 12			Clay, soft to stiff, same as above with chert	5YR 5/8 Yellowish red
48	7, 9, 9, 10			Clay, medium to stiff, plastic, weathered shale	5YR 5/8 Yellowish red
50	3, 10, 19, 15			Clay, soft to very stiff, very plastic, mixed chert fragments @ 49.5'	5YR 5/8 Yellowish red
52	4, 13, 10, 4			Auger refusal @ 51.8' in limy grey shale	
54					
56					
58					
60					
62					
64					
66					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D. D. Folse / J. L. Quillen Date 04/11/89 Page 1 of 3

Hole No. 23B Sample Interval ______ Total depth 49.4' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	8, 6, 5, 6			Clay, medium, plastic, with limestone fragments	5YR 5/6 Yellowish red
4	3, 4, 6, 7			Clay, soft to medium, small amounts of chert and organic streaking	5YR 5/6 Yellowish red
6	3, 9, 18, 21			Clay, soft to very stiff, plastic, mixed chert and limestone fragments @ 5.5'	5YR 5/6 Yellowish red
8	4, 7, 4, 5			Clay, soft to medium, same as above	5YR 5/6 Yellowish red
10	2, 3, 3, 5			Clay, soft to medium, same as above	5YR 5/6 Yellowish red
12	2, 2, 4, 4			Clay, soft, plastic, same as above	5YR 5/6 Yellowish red
14	2, 3, 3, 4			Clay, soft, plastic, same as above	5YR 6/4 Light reddish brown
16	1, 3, 3, 5			Clay, very soft to medium, same as above	5YR 6/4 Light reddish brown
18	5, 5, 7, 5			Clay, medium, same as above	5YR 6/4 Light reddish brown
20	6, 9, 9, 10			Clay, medium to stiff, large amount of chert fragments @ 19.5'	5YR 6/4 Light reddish brown
22	4, 3, 3, 3			Clay, soft, plastic, limestone and chert fragments	5YR 5/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D. D. Folse / J. L. Quillen Date 04/11/89 Page 2 of 3

Hole No. 23B Sample Interval ____ Total depth 49.4' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	8, 9, 4, 6			Clay, soft to medium, large amounts of mixed chert @ 23.0'	5YR 5/6 Yellowish red
26	1, 2, 3, 4			Clay, very soft to soft, same as above	5YR 5/6 Yellowish red
28	3, 5, 7, 9			Clay, very soft to stiff, same as above	5YR 5/6 Yellowish red
30	2, 5, 5, 17			Clay, soft to very stiff, very weathered shale	5YR 5/8 Yellowish red
32	13, 17			Clay, soft to very stiff, very plastic, chert layer @ 30.8'	5YR 5/8 Yellowish red
34	3, 4, 6, 9			Clay, soft to stiff, very plastic, weathered shale and silt	5YR 5/8 Yellowish red
36	2, 4, 7, 9			Clay, soft to stiff, same as above	5YR 5/8 Yellowish red
38	2, 10, 9, 8			Clay, soft to stiff, chert layer @ 38.0'	5YR 5/8 Yellowish red
40	2, 5, 11, 12			Clay, soft to stiff, same as above	5YR 5/8 Yellowish red
42	7, 7, 9, 10			Clay, medium to stiff, weathered shale @ 41.3', organic layer @ 42.0'	5YR 5/8 Yellowish red
44	10, 11, 15, 15			Clay, stiff to very stiff, cross bedded weathered shale @ 43.8'	5YR 5/8 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By D. D. Foise / J. L. Quillen   Date 04/11/89 Page 3 of 3
Hole No. 23B Sample Interval ____ Total depth 49.4' Sample Type 2' X 1.5" Split Spoon
Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig
Project K-1070- A Data Verified By ____ Date Verified ____

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	4 6 8 9			Clay, medium to stiff, weathered shale, plastic	5YR 5/8 Yellowish red
48	11 13 14 17			Clay, stiff to hard, sample refusal @ 49.4' in chert	
50	13 25/.3				
52					
54					
56					
58					
60					
62					
64					
66					

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Zutman   Date 01/20/89 Page 1 of 2

Hole No. 24 Sample Interval ______ Total depth 62.8' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates   Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A   Data Verified By ______   Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
2	6, 5, 7, 8			Clay, medium, top 1" topsoil, with mixed chert and minor amounts of silt, damp	5YR 4/6 Yellowish red
4	2, 3, 6, 7			Clay, soft to medium, same as above with some limestone fragments	5YR 4/6 Yellowish red
6	2, 3, 3, 3			Clay, soft, plastic, moist	5YR 4/6 Yellowish red
8	1, 2, 3, 5			Clay, soft to medium, with some rock fragments	5YR 4/6 Yellowish red
10	3, 4, 6, 3			Clay, soft to medium, some roots from 8.0 to 9.0', large fragments of chert scattered throughout, some dolomite, damp to moist	5YR 4/6 Yellowish red
12	4, 6, 13, 14			Clay, medium to stiff, very plastic, large cherty dolomite @ 11.2', damp	5YR 4/6 Yellowish red
14	7, 4, 4, 4			Clay, medium, same as above with large chert fragments to 1"	5YR 4/6 Yellowish red
16	3, 4, 6, 8			Clay, soft to medium, high % rock fragments, small cherty dolomite fragments	5YR 4/6 Yellowish red
18	5, 5, 6, 5			No sample, obstruction	
20	3, 6, 6, 6			No sample, drillers used shelby tube to go past obstruction	
22	7, 3, 4, 5			Clay, medium, some sand and silt, dolomite and chert fragments, dolomite severely weathered, moist	5YR 4/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Zutman Date 01/20/89 Page 2 of 3

Hole No. 24 Sample Interval ______ Total depth 62.8' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
24	2, 3, 4, 4			Clay, same as above grading to more plastic and moist @ 23.0'	5YR 5/6 Yellowish red
26	2, 3, 4, 5			Clay, soft to medium, mottled with some yellow brown clay, very sticky and plastic	5YR 5/6 Yellowish red
28	2, 3, 4, 4			Clay, soft, a few rock fragments @ 26.5', moist	5YR 5/6 Yellowish red
30	2, 2, 3, 4			Clay, same as above	5YR 5/6 Yellowish red
32	2, 2, 2, 3			Clay, same as above, wet @ 30.5 to 31.0', then grades back to moist, sticky	5YR 5/6 Yellowish red
34	1, 2, 2, 3			Clay, same as above, wet @ 32.0 to 33.0' then grading to moist and sticky	5YR 5/6 Yellowish red
36	1, 1, 1, 2			Clay, very soft, same as above	5YR 5/6 Yellowish red
38	1, 1, 2, 2			Clay, very soft to soft, becoming mottled near bottom of the shoe	5YR 5/6 Yellowish red
40	1, 1, 1, 3			Clay, very soft, same as above, rock fragments near bottom of the shoe	5YR 5/6 Yellowish red
42	3, 2, 1, 2			Clay, very soft to soft, mottled, a few rock fragments	5YR 5/6 Yellowish red
44	1, 1, 5, 9			Clay, very soft to medium, large chert fragments near shoe	5YR 5/6 Yellowish red

BOREHOLE SUMMARY INFORMATION

Oak Ridge National Laboratory

Prepared By J. L. Zutman Date 01/20/89 Page 3 of 3

Hole No. 24 Sample Interval ______ Total depth 62.8' Sample Type 2' X 1.5" Split Spoon

Drilling Contractor Geologic Associates Rig Type CME 450 All Terrain Drill Rig

Project K-1070- A Data Verified By ______ Date Verified ______

DEPTH (FEET)	BLOWS 6"	SAMPLE INTERVAL	LITHOLOGY	DESCRIPTION	
46	2 4 11 11			Clay, soft to stiff, soupy to 45.5', large rock fragments near bottom of shoe	5YR 4/6 Yellowish red
48	3 5 7 3			Clay, medium, with chert	5YR 4/6 Yellowish red
50	5 9 11 7			Clay, medium to stiff, with chert and dolomite	5YR 4/6 Yellowish red
52	3 1 3 4			Clay, very soft to soft, with minor amounts of silt and assorted chert fragments	5YR 4/6 Yellowish red
54	1 2 1 2			No sample, very soft	
56	1 1 1 2			Clay, very soft to soft, cherty, grading to a very fine, well sorted sand @ 55.0'	5Y 7/2 Yellowish gray
58	2 1 1 3			Clay, sandy, fine to medium grained	5YR 4/6 Yellowish red
60	1 1 1 3			Clay, sandy, very soft to soft, a few chert fragments	5YR 4/6 Yellowish red
62	1 1 1 3			Clay, sandy, very soft to soft, fine grained	5YR 4/6 Yellowish red
64				Limestone, sample refusal @ 62.8', hard, wet, similar to a slurry	
66					

Appendix B

DISPOSAL INVENTORY

K-1070-A CONTAMINATED BURIAL GROUND DISPOSAL INVENTORY

The following is an itemized list of the contents of the various graves which make up the K-1070-A Contaminated Burial Ground. The information is a compilation based on files obtained from the Oak Ridge Gaseous Diffusion Plant Health and Environmental Affairs Department.

Table B.1 Itemized manifest of contents of K-1070-A Contaminated Burial Ground graves

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
1–7	unknown	Alumina and carbon from K-1131 absorption traps	unknown	unknown
8	19 boxes	Scrap metal-Fairchild operation	unknown	unknown
	3 × 55 gal	Thorium oxide	unknown	unknown
	32 × 6 gal	Thorium fluoride	unknown	unknown
	55 drums	Thorium slag	unknown	unknown
	20 drums	Cell cleanout	unknown	unknown
	3 × 55 gal	"Duds"	unknown	unknown
9	53 × 55 gal	Sheared feed, press cake, cell cleanout from thorium operation	unknown	unknown
10	39 × 55 gal	Thorium and magnesium-NASA project	unknown	unknown
11	5 drums	Vitro fines	unknown	unknown
	2 drums	National lead fines	unknown	unknown
	3 drums	National lead vacuum cleanings	unknown	unknown
12	unknown	Thorium drums (empty)	unknown	unknown
	350	Obsolete UF_6 product cylinders	unknown	unknown
13	2 drums	Uranium chips and magnesium thorium	unknown	unknown
	2 × dump truck	Bagged gravel-K-601 roof	unknown	unknown
	2 × dump truck	Tar and felt-K-601 roof	unknown	unknown
	40 AS[a] cans	From 8A	unknown	unknown
14	7 AS cont. w/dollies	Contaminated MFL oil-K1420	unknown	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	220 × 5 gal	Buckets-National Lead shipment	unknown	unknown
	6 boxes	Equipment-K-1004D	unknown	unknown
	3.5 dump trucks	Gravel etc-K-601 roof	unknown	unknown
	6 bottles	Depleted material-University of Virginia	unknown	unknown
	1 AS can	MgF_2 and NaF (Code 209)	unknown	unknown
	1 dump truck	K-1131 stack (4 sect.)	unknown	unknown
	6 dump trucks	Roof material-K-1420	unknown	unknown
15	3 × 5 gal	K-1131 stack material	unknown	unknown
	12 dump trucks	K-1420 roof material	unknown	unknown
	1 tallboy	NaF and MgF_2-Lab A	unknown	unknown
	1 drum	NaF and depleted U-K-1413	unknown	unknown
	98 AS cans	U_3O_8 from 8A	unknown	unknown
	67	Containers (empty)[b]	unknown	unknown
	40 × 55 gal	Container (empty)[b]	unknown	unknown
	8 × 30 gal	Container (empty)[b]	unknown	unknown
	12 × 5 gal	Container (empty)[b]	unknown	unknown
	1 × 30 gal	MgF_2	unknown	unknown
	2 × 5 gal	Bucket-BrF_3	unknown	unknown
	1 × 5 gal	Buck-$AlBrF_3$	unknown	unknown
16	17 dump trucks	K-1420 roof material	unknown	unknown
	35 AS cans	U_3O^8 from 8A	unknown	unknown
	8 × 55 gal	Drums (empty)[c]	unknown	unknown
17	2 boxes	Chemicals	unknown	unknown
	14 × 55 gal	Drums (empty)[c]	unknown	unknown
	6 × 30 gal	Drums (empty)[c]	unknown	unknown
	49 × 55 gal	Drums (empty)[b]	unknown	unknown
	31 × 30 gal	Drums (empty)[b]	unknown	unknown
	27 × 5 gal	Buckets (empty)[b]	unknown	unknown
	28	Tallboy containers[b]	unknown	unknown
	48 AS cans	Cans (empty)[b]	unknown	unknown
	31 × 55 gal	Drum (empty)	unknown	unknown
	27 × 30 gal	Drum (empty)	unknown	unknown
	4 AS cans	Cans (empty)	unknown	unknown
	5	MD cylinders	unknown	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	1 × 20 gal	Can-beryllium oxide	unknown	unknown
		Instrument manifold from Lab D	unknown	unknown
	1 × 30 gal	Drum-UO_2F_2	unknown	unknown
	24 × 30 gal	Drums (empty)[c]	unknown	unknown
	14 AS cans	Material-K-1131 stack	unknown	unknown
		section K-1131 stack	unknown	unknown
	5 AS cans	Cans contaminated with MFL oil	unknown	unknown
	24 AS cans	Cans	unknown	unknown
	6 × 30 gal	Drums	unknown	unknown
	4	Tallboys	unknown	unknown
	1 × 5 gal	Container	unknown	unknown
18	2	10-ton cylinders	unknown	unknown
	75 × 5 gal	Buckets[d]	unknown	unknown
	5 × 55 gal	Drums of bottles[d]	unknown	unknown
	2 boxes	Residue-K-33 equipment	unknown	unknown
	48	Cylinders (contaminated)	unknown	unknown
	4 × 30 gal	Drums (empty)	unknown	unknown
	4 × 55 gal	Drums (empty)	unknown	unknown
	1 filter	Pu and Be contaminated	unknown	unknown
	2	2.5 ton cylinders	unknown	unknown
	5 × 55 gal	Drums (empty)	unknown	unknown
	6 AS cans	Al contaminated with WF_6	unknown	unknown
	1 × 30 gal	Drum (empty)	unknown	unknown
	1 × 20 gal	Can with Th, Be, U contaminated material	unknown	unknown
	1	Plastic tallboy	unknown	unknown
	10 × 55 gal	NaF with depleted UF_6	unknown	unknown
	2 × 55 gal	Drums (empty)[c]	unknown	unknown
	1 × 30 gal	Drums (empty)[c]	unknown	unknown
	1 × 5 gal	Filter paper with Th	unknown	unknown
	4 × 55 gal	Drums (empty)[d]	unknown	unknown
	1 AS can	Al contaminated with depleted U	unknown	unknown
	1 jar	MgF[d]	unknown	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	1 × 5 gal	Bucket of valves	unknown	unknown
	26 × 55 gal	Drums with depleted UF_6	unknown	unknown
	6 × 55 gal	Drums	unknown	unknown
	7 × 5 gal	Sludge-K-1420	unknown	unknown
	12 × 30 gal	Drums K-1420 (empty)	unknown	unknown
	6 × 55 gal	Drums K-1420 (empty)	unknown	unknown
	7 × 5 gal	Bucket K-1420 (empty)	unknown	unknown
	1 can	Be from K-1004-D	unknown	unknown
	1 tank	Lead lined from Peninsula	unknown	unknown
	1 GI can	Plutonium wasted-Lab C	unknown	unknown
	1 cylinder	#39256 from K-1004-L	unknown	unknown
	37	Containers K-1420	unknown	unknown
	1 × 10 gal	Depleted U turnings	unknown	unknown
	4 cans	"gunk" K-1131	unknown	unknown
	64	Containers from Vault 8A (empty)	unknown	unknown
	1 × 30 gal	Scrap K-1004-D	unknown	unknown
	1 × 5 gal	Be chips K-1025	unknown	unknown
	54 × 55 gal	Drums (empty)	unknown	unknown
19	1	Container scrap metal	unknown	unknown
	26 × 55 gal	Oil drums (empty)	unknown	unknown
	68	Cans from Vault 8A	unknown	unknown
	6 × 5 gal	Buckets of Te K-1413	unknown	unknown
	2 × 55 gal	Drums of Te K-1413	unknown	unknown
	3 GI cans	Oily rags K-33	unknown	unknown
	2 × 5 gal	Be scrap	unknown	unknown
	1 gal	Can K-1006	unknown	unknown
	24 × 30 gal	Drums NaF K-1413	unknown	unknown
	12	Containers K-1420	unknown	unknown
	15	Containers of oil	unknown	unknown
	3	Containers of screenings K-1420	unknown	unknown
	72 × 5 gal	Buckets K-1420	unknown	unknown
	6 cylinders	From K-1405	unknown	unknown
	11 cylinders	Contents unknown	unknown	unknown
	147	Containers contents unknown	unknown	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	17 × 30 gal	Drums contents unknown	unknown	unknown
	30 × 55 gal	Drums contents unknown	unknown	unknown
	64 × 55 gal	Drums (empty)	unknown	unknown
	33	Drums (empty)	unknown	unknown
		Material from Y-12 810 acct. transfer 9014	unknown	unknown
	1 GI can	Scrap from K-1131	unknown	unknown
	11 cylinders	From stores	unknown	unknown
20	167	Containers of nuclear scrap	4148	<5%
	123	Containers of nuclear scrap	unknown	<0.9%
	67	Containers of nuclear scrap	unknown	>0.9%<10%
21	45 × 5 gal	Containers of nuclear scrap	unknown	unknown
	1 × 5 gal	Bucket of D38 metal	unknown	unknown
	89	Containers misc. scrap	unknown	unknown
	108	Containers misc. scrap	unknown	unknown
	43 × 5 gal	Cont. Al_2O_3	640	<5%
	5 × 55 gal	Cont. Al_2O_3	unknown	unknown
	100	Cans (empty)	unknown	unknown
	20 × 55 gal	Drums (empty)	unknown	unknown
	51 × 30 gal	Drums (empty)	unknown	unknown
	64 × 5 gal	Buckets (empty)	unknown	unknown
	14 × 5 gal	Soda lime and salt	unknown	unknown
	2 × 5 gal	Unknown solid waste	unknown	unknown
	1 × 5 gal	Carbon and Al_2O_3	unknown	unknown
	1 × 5 gal	Unknown liquid lab waste	unknown	unknown
	2 × 30 gal	Carbonate solution	unknown	unknown
	5 × 30 gal	Vacuum cleanings	unknown	unknown
	2	NaF-individually safe cans	unknown	unknown
	1	Soda salt and Al_2O_3 in individually safe cans	unknown	unknown
22	86 × 5 gal	Leached Al_2O_3	991	<5%
	42 × 5 gal	Contaminated Al_2O_3	unknown	unknown
23	34	Misc. U scrap	1,145	<2%
	9 × 5 gal	MFL filter cake	unknown	<2%
	1 × 5 gal	Solid waste	unknown	<2%
	4 × 5 gal	NaF	unknown	<2%

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	2 × 5 gal	Soda, salt, Al_2O_3	unknown	<2%
	13 × 5 gal	Container (empty)[e]	unknown	<2%
	3 × 5 gal	Container (empty)[f]	unknown	<2%
	1 × 5 gal	Container (empty)[g]	unknown	<2%
24	53 × 5 gal	Leached Al_2O_3	930	unknown
25	9	Misc. U scrap	200	<5%
	1 × 5 gal	Soda lime and salt	unknown	unknown
	5 × 5 gal	MFL filter cake	unknown	unknown
	1 × 5 gal	Solid waste	unknown	unknown
	1 × 5 gal	NaF	unknown	unknown
	1 individ. safe can	Al_2O_3	unknown	unknown
26	18	Misc. U scrap	1,200	<3%
	5 individ. safe cans	Al_2O_3	unknown	unknown
	2 × 5 gal	Soda, salt, Al_2O_3	unknown	unknown
	2 individ. safe cans	Solid waste	unknown	unknown
	9 × 5 gal	MFL filter cake	unknown	unknown
27	13	Misc. U scrap	600	<5%
	8 individ. safe cans	Al_2O_3	unknown	unknown
	1 × 5 gal	MFL filter cake	unknown	unknown
	3 × 5 gal	Containers (empty)[f]	unknown	unknown
	1 × 5 gal	Containers (empty)[g]	unknown	unknown
28	45 × 5 gal	Leached Al_2O_3	240	<5%
29	23 × 5 gal	Leached Al_2O_3	345	<5%
30	23 × 5 gal	Leached Al_2O_3	138	<5%
31	21 × 5 gal	Leached Al_2O_3	274	<5%
	12 × 5 gal	Leached Al_2O_3	unknown	unknown
32	12 × 5 gal	Leached Al_2O_3	193	<5%
33	32 × 5 gal	Leached Al_2O_3	246	<5%
34	25 × 5 gal	Leached Al_2O_3	868	<5%
35	25 × 5 gal	Leached Al_2O_3	582	<5%
36	30 × 5 gal	Leached Al_2O_3	858	<5%
37	40 × 5 gal	Leached Al_2O_3	1145.8	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
38	39 × 5 gal	Leached Al_2O_3	522.5	unknown
39	48 × 5 gal	Leached Al_2O_3	825	unknown
40	49 × 5 gal	Leached Al_2O_3	1010	unknown
41	40 × 5 gal	Leached Al_2O_3	1169.4	unknown
42	110 × 5 gal	Leached Al_2O_3	1045.9	unknown
43	21 × 5 gal	Leached Al_2O_3	835	unknown
	10 × 5 gal	MFL filter cake	39	unknown
44	22 × 5 gal	Leached Al_2O_3	220	unknown
45	42 × 5 gal	Leached Al_2O_3	374	unknown
46	47 × 5 gal	Leached Al_2O_3	896	unknown
47	16 × 5 gal	K-1413 scrap[h]	unknown	unknown
	3 × 30 gal	K-1413 scrap[h]	30.593	unknown
48	1 × 5 gal	K-1413 scrap[h]	94.483	unknown
	3 × 30 gal	K-1413 scrap[h]	157.45	unknown
49	2 × 30 gal	K-1413 scrap[h]	416	unknown
50	3 × 30 gal	K-1413 scrap[h]	25.319	unknown
51	3 × 30 gal	K-1413 scrap[h]	24.881	unknown
52	3 × 30 gal	K-1413 scrap[h]	591.960	unknown
53	7 × 30 gal	Screened tails-K-1231	unknown	unknown
	4 × 10 gal	Rags	unknown	unknown
	1 × 5 gal	Rags	unknown	unknown
	2 × 55 gal	Zorball	unknown	unknown
	8	Tallboys (empty)	unknown	unknown
	2	Tallboys-Zorball	unknown	unknown
	1 × 55 gal	Low assay material	unknown	unknown
	3	Tarps	unknown	unknown
	3	Cell heaters	unknown	unknown
	1 × 30 gal	Drums (empty)	unknown	unknown
	4 × 5 gal	Containers (empty)	unknown	unknown
	14 × 1 gal	Containers (empty)	unknown	unknown
	1 × .5 gal	Container (empty)	unknown	unknown
	22 individ. safe cans	Cans (empty)	unknown	unknown
	15 × 30 gal	Scrap material[i]	unknown	unknown
	1 × 5 gal	Scrap material	unknown	unknown
	4	51622 grams Th scrap	unknown	unknown

Table B.1 (continued)

Grave No.	Containers	Description	^{235}U (grams)	Enrichment
54	3 × 5 gal	Scrap	unknown	unknown
	1 × 1 gal	Scrap	unknown	unknown
	23 × 30 gal	Misc. scrap	unknown	unknown
	3 × 55 gal	Misc. scrap	unknown	unknown
	67 × 55 gal	Al_2O_3	unknown	unknown
55	3 × 30 gal	Incinerator ash[j]	unknown	unknown
56	1 × 30 gal	Incinerator ash[j]	unknown	unknown
	2 × 30 gal	K-1413 scrap[h]	83.14	unknown
57	1 × 55 gal	K-1413 scrap[h]	2725.18	unknown
	8 × 5 gal	K-1413 scrap[h]	183.17	unknown
58	1 × 55 gal	K-1413 scrap[h]	2552.38	unknown
	6 × 6 gal	K-1413 scrap[h]	39.99	unknown
59	14 × 5 gal	Leached Al_2O_3	unknown	unknown
60	2 × 30 gal	Incinerator ash[j]	958	unknown
	3 individ. safe cans	Incinerator ash[j]	54	unknown
61	2 × 30 gal	Incinerator ash[j]	911	unknown
	3 individ. safe cans	Incinerator ash[j]	46	unknown
62	30 × 5 gal	Leached Al_2O_3	284.46	unknown
	14 small jars	Misc. material	13.0	unknown
63	28 × 5 gal	Leached Al_2O_3	318.75	unknown
	13 × 15" cans	Incinerator ash[j]	286.9	<0.7%
64	11	Contents unknown	163	unknown
	15 × 5 gal	Contents unknown	3202	unknown
65	20 × 15 1.	MFL oil	unknown	unknown
	1 × 5 gal	Zr shavings	unknown	unknown
	1 can	Zr shavings	unknown	unknown
	11 × 55 gal	Al_2O_3	2038.5	unknown
	1 × 300 ml	Unknown	unknown	unknown
	6 × 100 g	Arsenic oxide	unknown	unknown
	1 × 100 g	Arsenic metal	unknown	unknown
	1 × 100 g	Anhydrone	unknown	unknown
	1 × 500 g	Lead nitrate	unknown	unknown
	1 bottle	Antimony chloride	unknown	unknown
66	15 × 5 gal	Al_2O_3, U_3O_8	unknown	unknown

Table B.1 (continued)

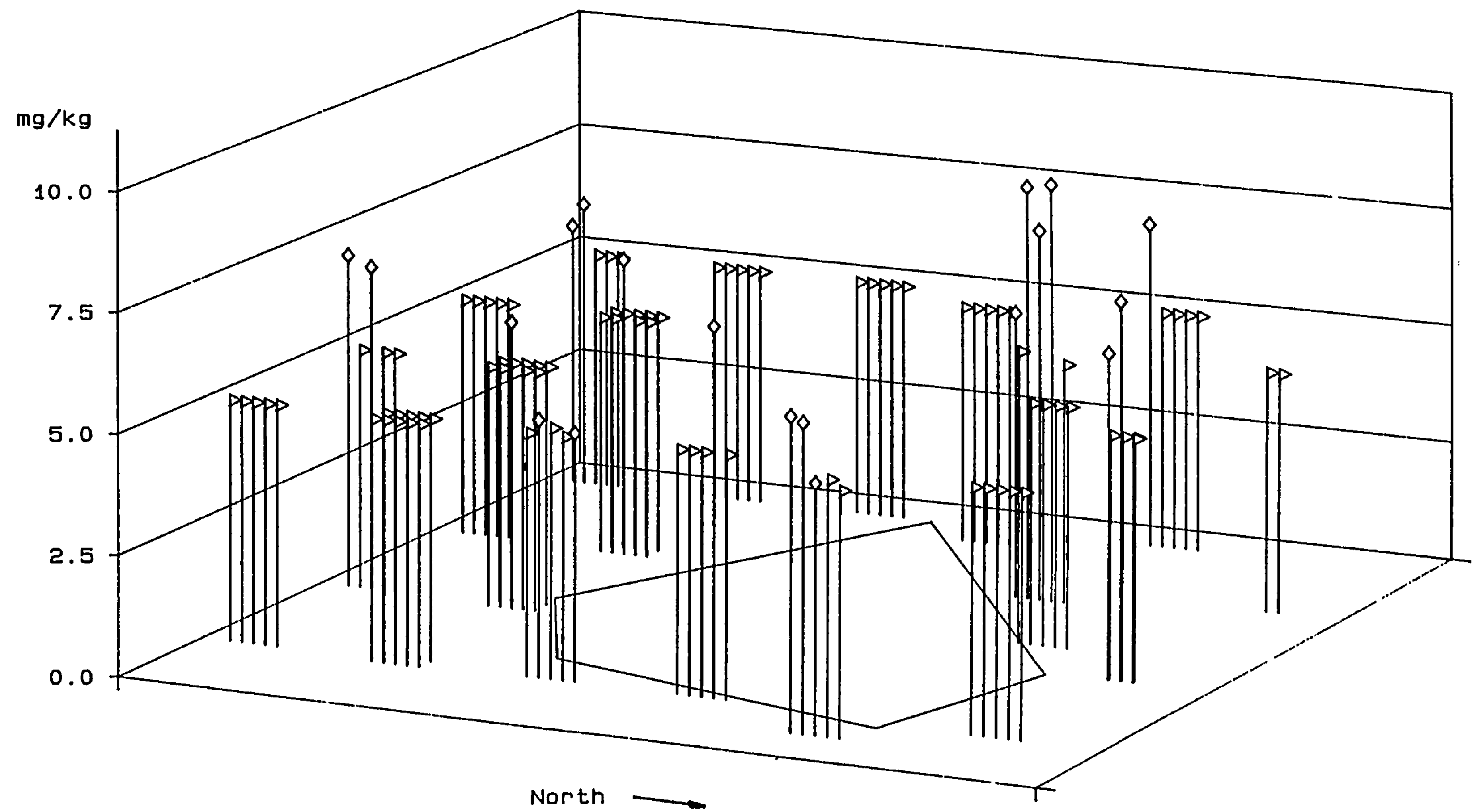
Grave No.	Containers	Description	^{235}U (grams)	Enrichment
	17 × 5 gal	Leached Al_2O_3, filters	145.9	unknown
67	14 × 5 gal	Leached Al_2O_3, filters	113.0	unknown
	8 × 5 gal	Filters from centrifuge	54.45	unknown

[a]Indicated an ALWAYS SAFE type container.
[b]Previously contained low U solutions.
[c]Previously contained carbonate solutions.
[d]Previously contained uranium oxide from 1X.
[e]Previously contained thorium plating solution.
[f]Previously contained UF_6 and coolant.
[g]Previously contained lab waste.
[h]See NSC #177 for burial of K-1413 scrap.
[i]IGNITION DANGER-one drum contains glass bottle filled with thorium.
[j]See NSC #180 for burial of incinerator ash.

Appendix C

THREE-DIMENSIONAL CONCENTRATION DISTRIBUTION PLOTS

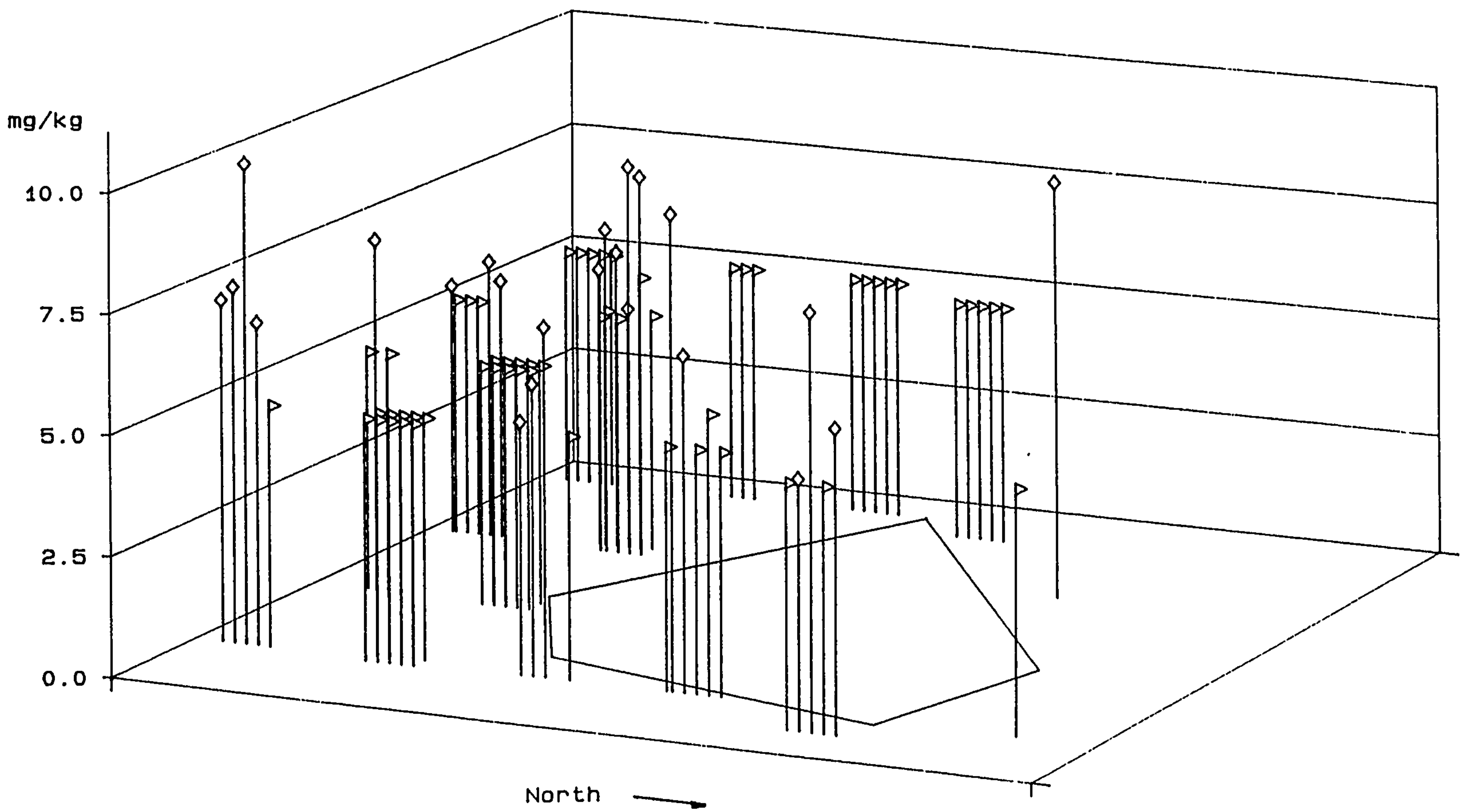
Antimony at K–1070–A
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Antimony at K-1070-A

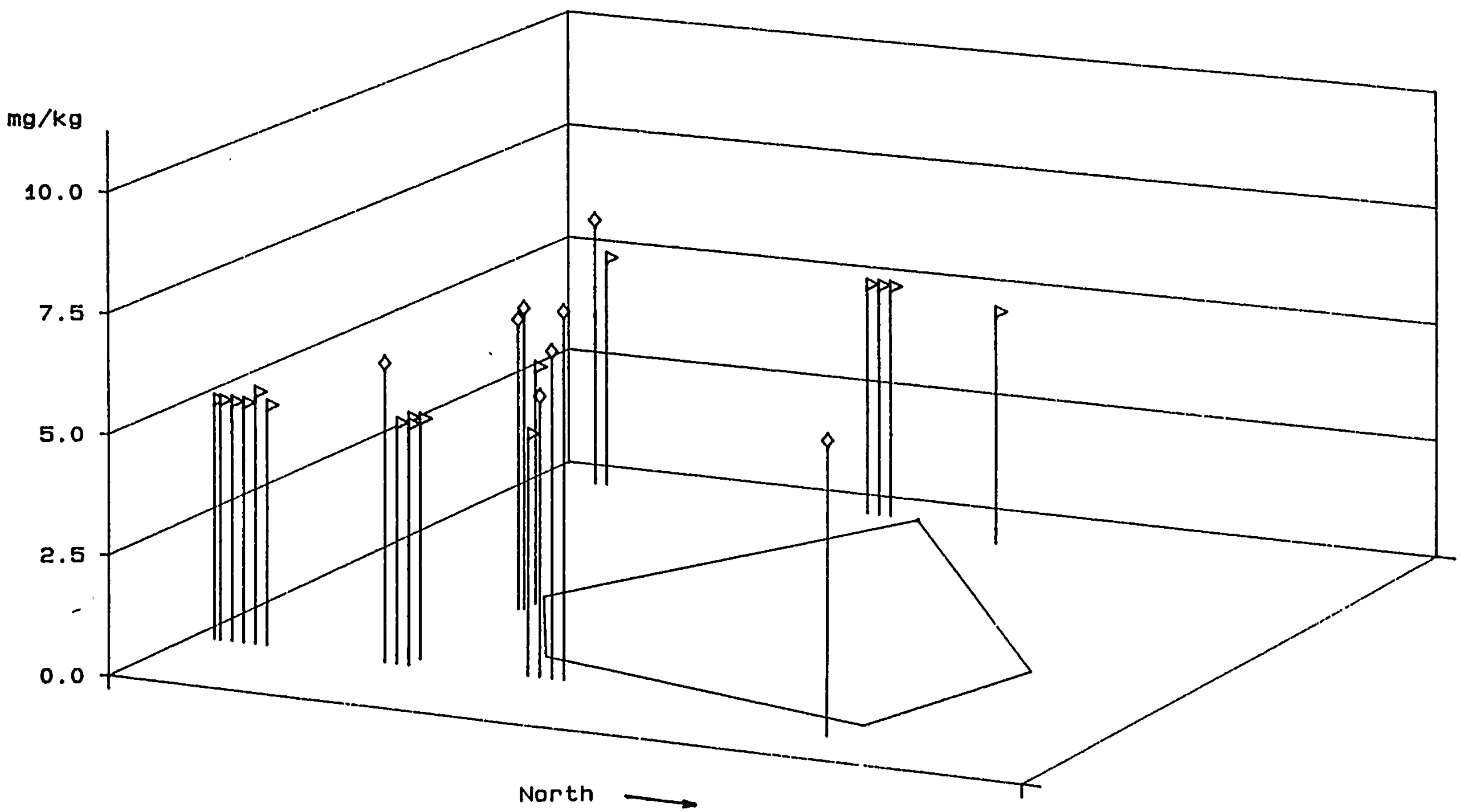
Depths= 20 to 40 Ft.



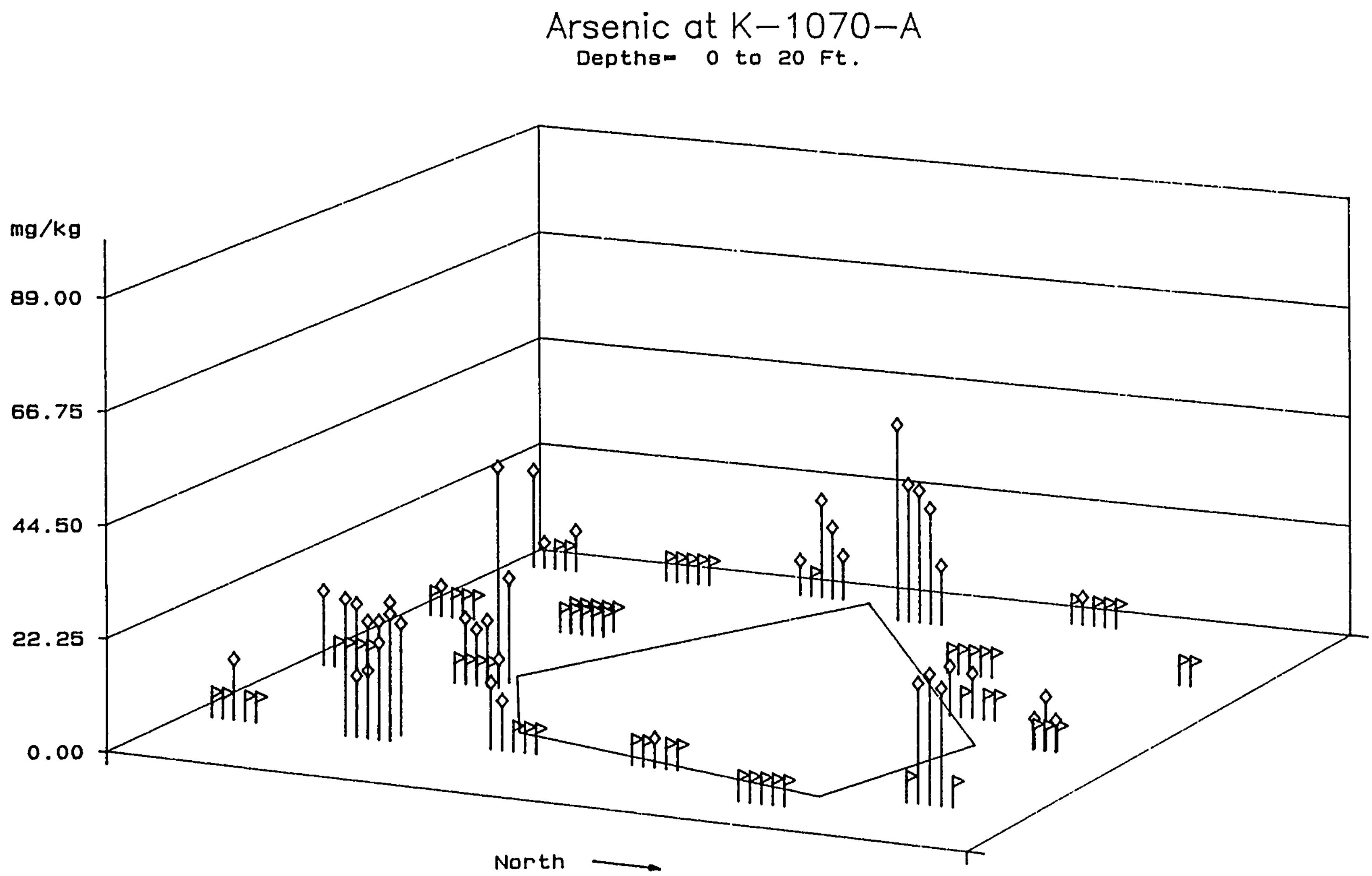
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Antimony at K–1070–A

Depths= > 40 Ft.

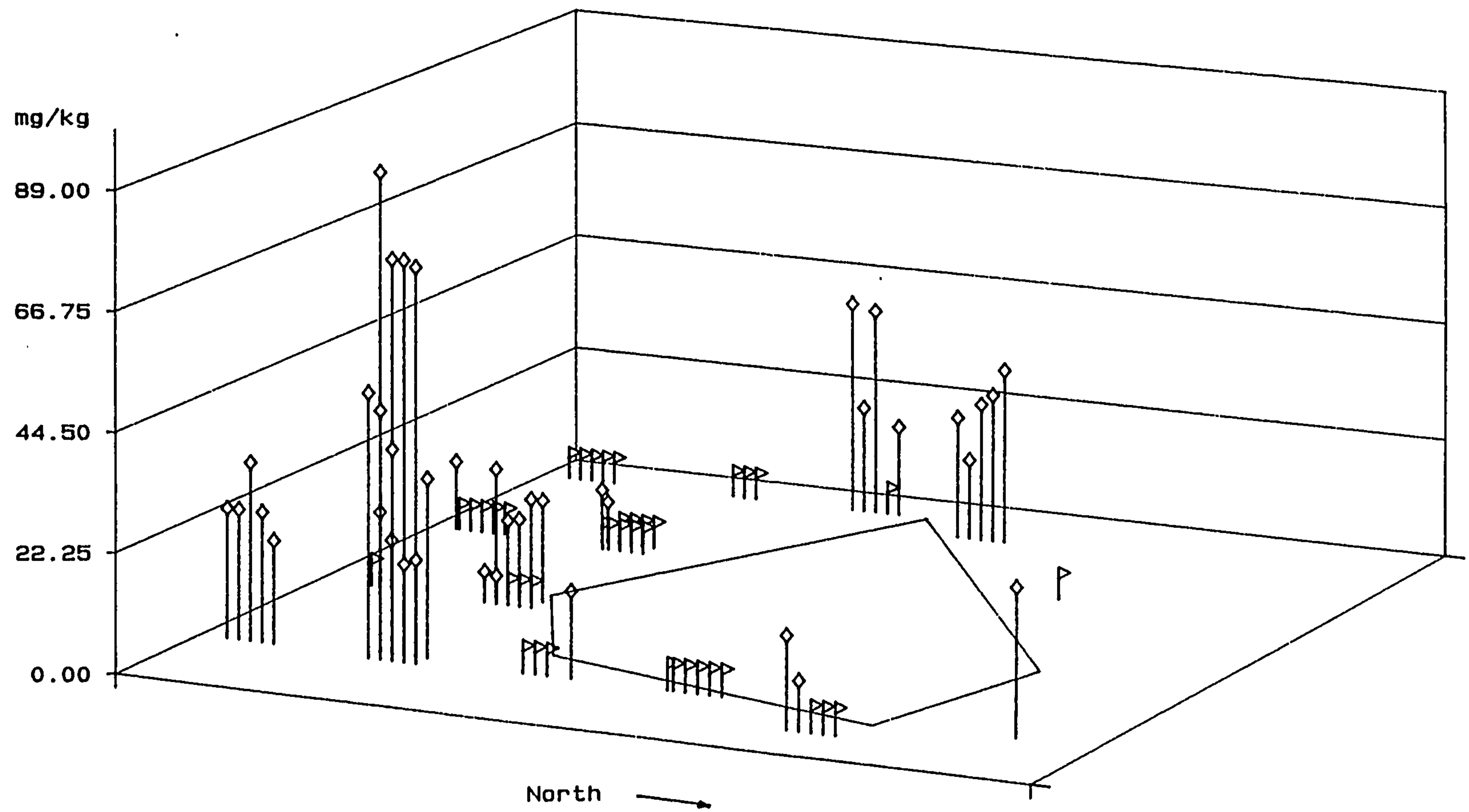


4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data



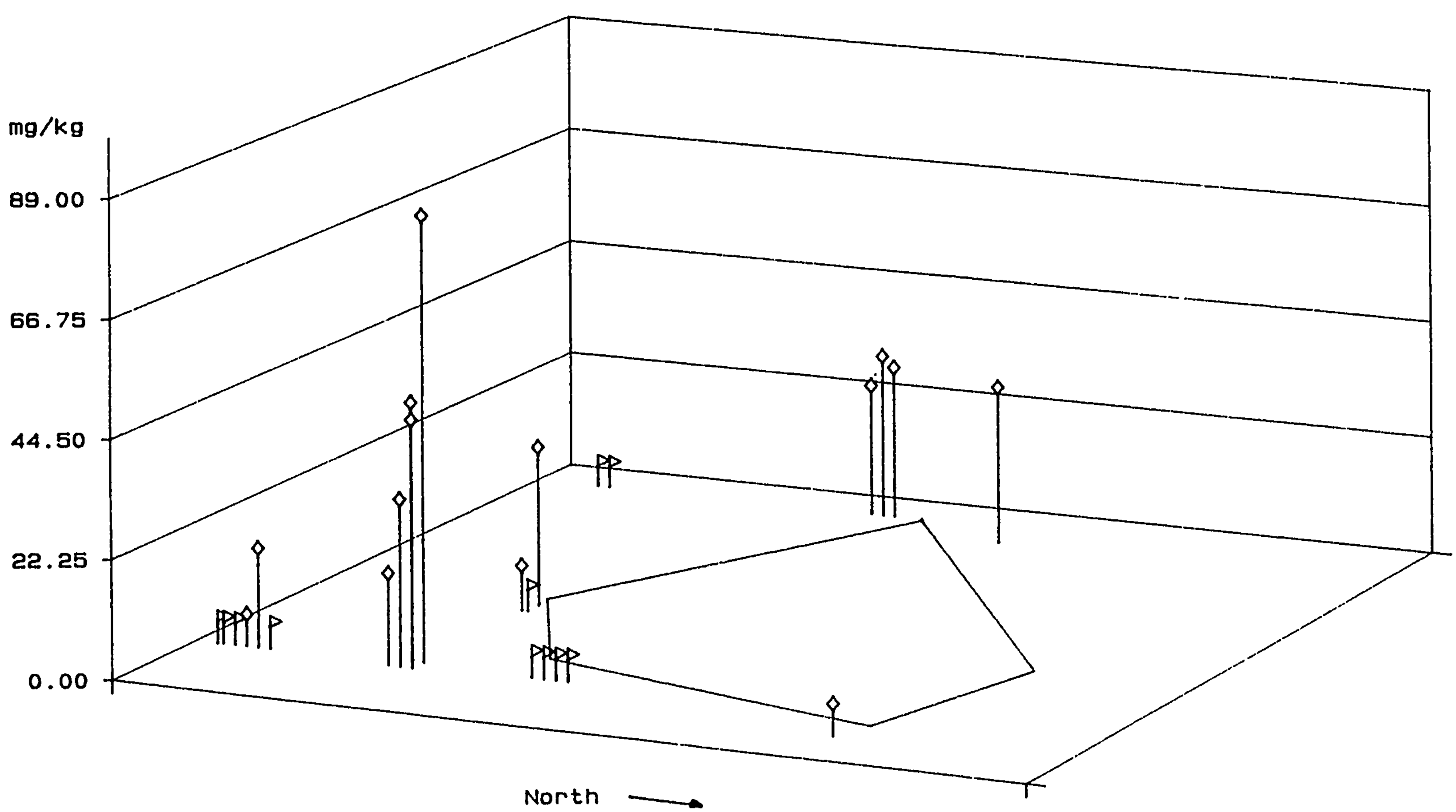
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Arsenic at K–1070–A
Depths= 20 to 40 Ft.



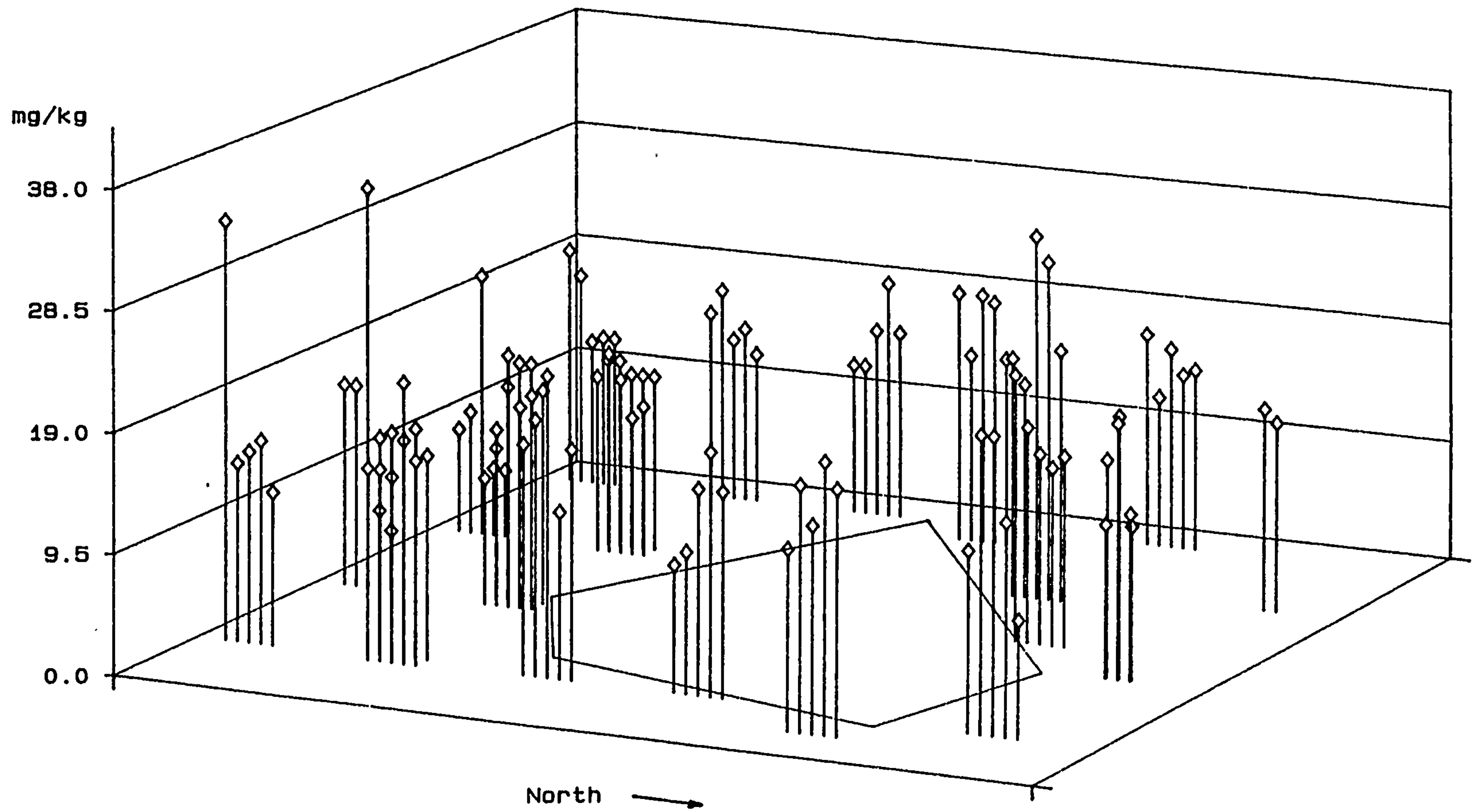
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Arsenic at K–1070–A
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

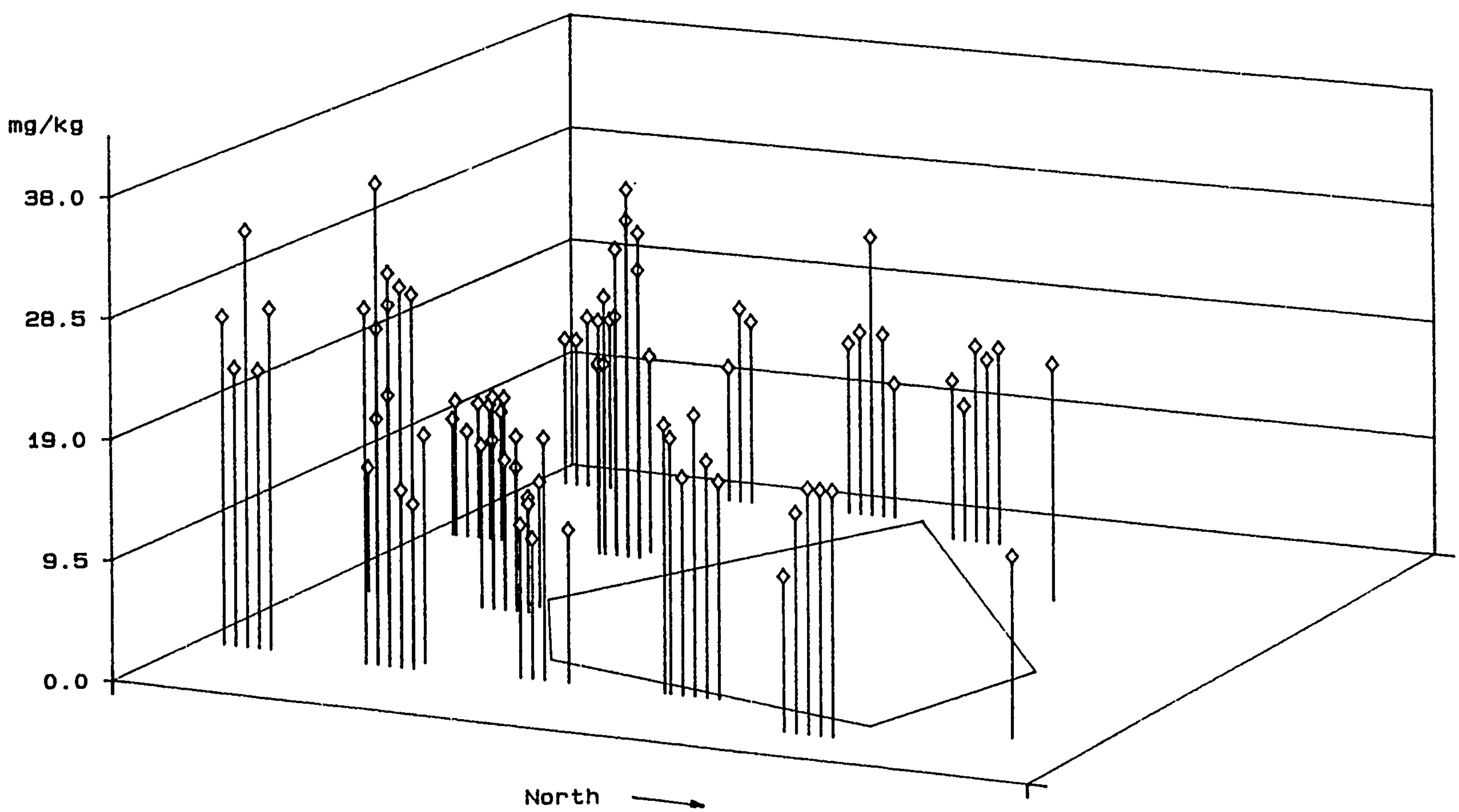
Chromium at K-1070-A
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

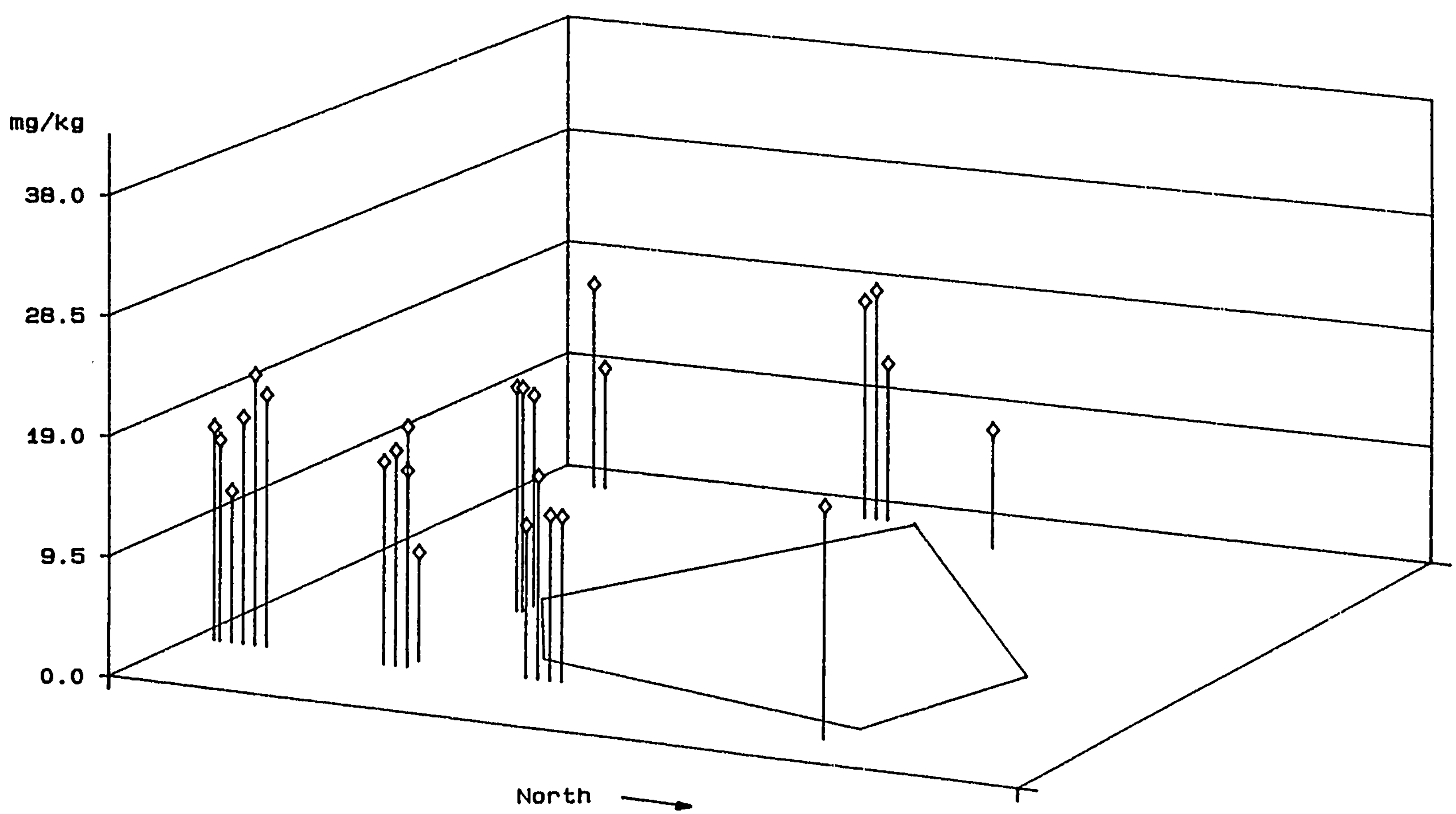
Chromium at K–1070–A

Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

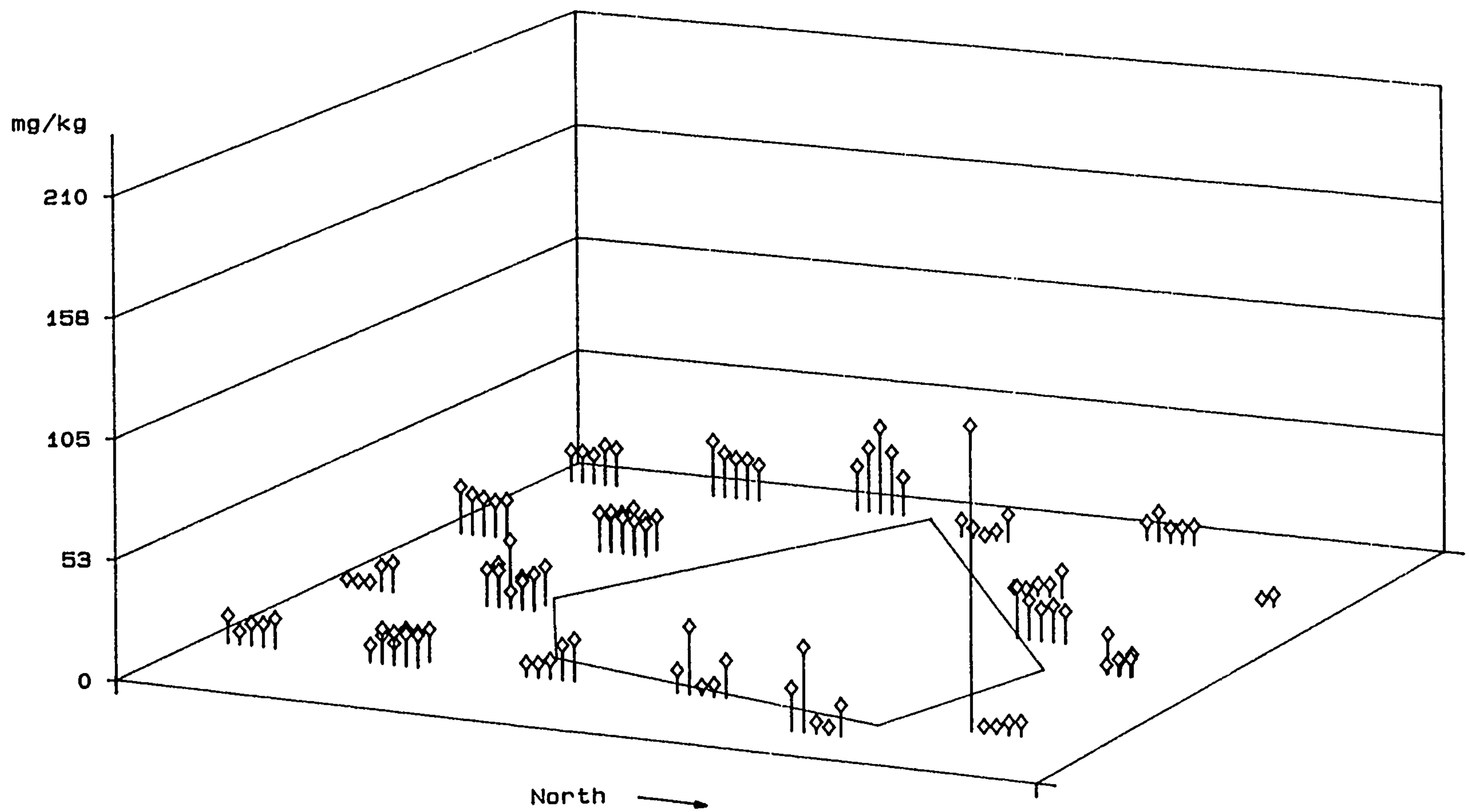
Chromium at K–1070–A
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Cobalt at K−1070−A

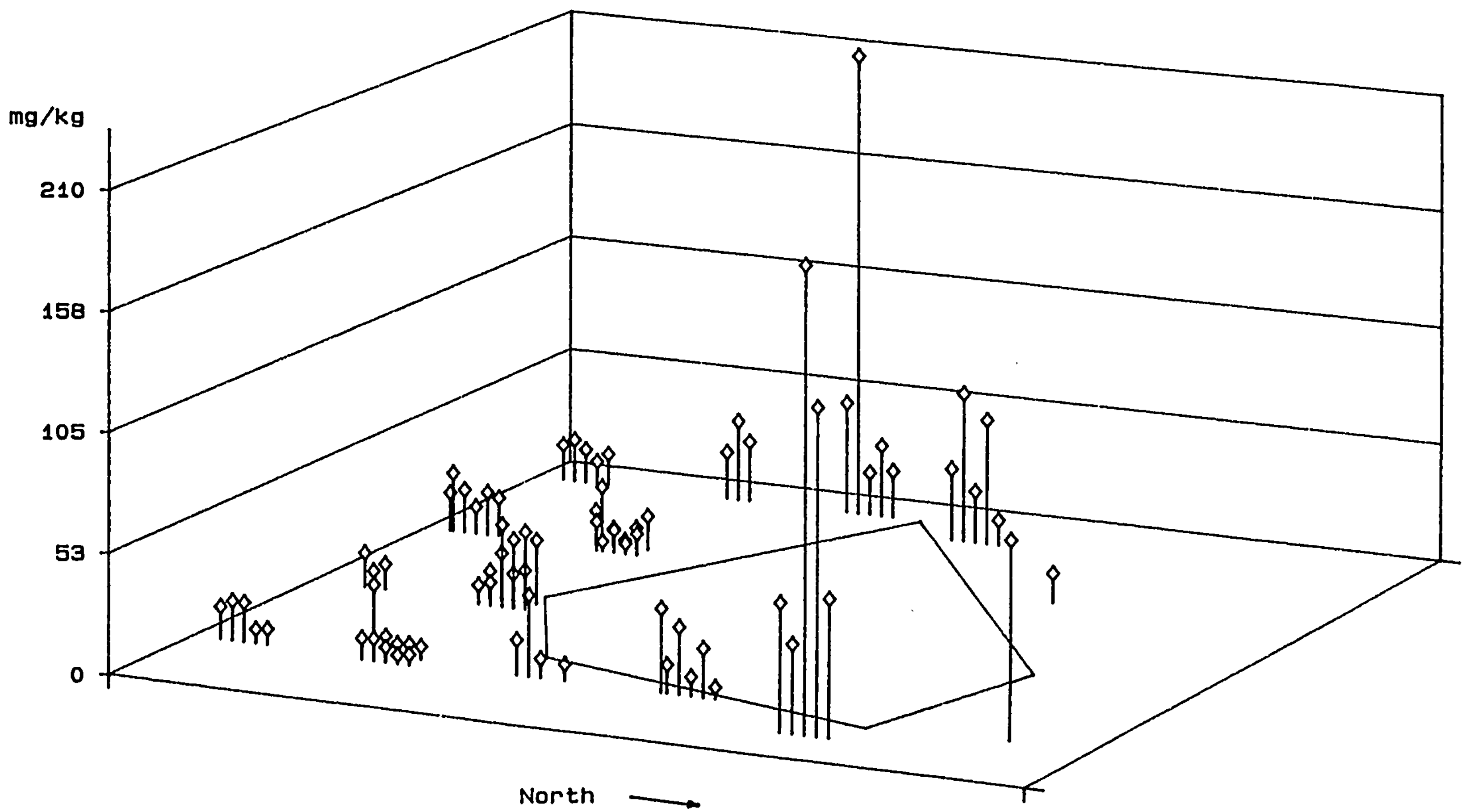
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

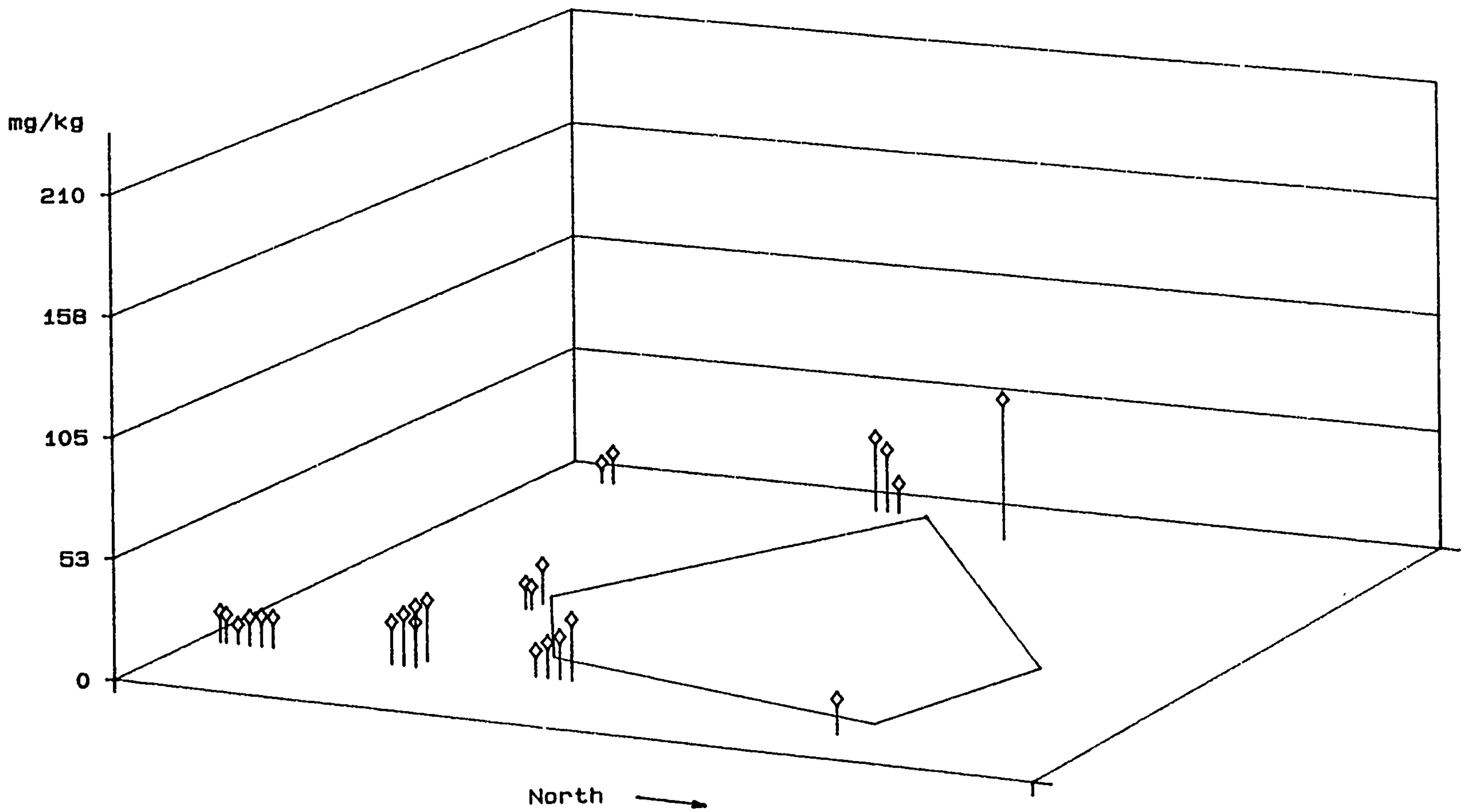
Cobalt at K-1070-A

Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

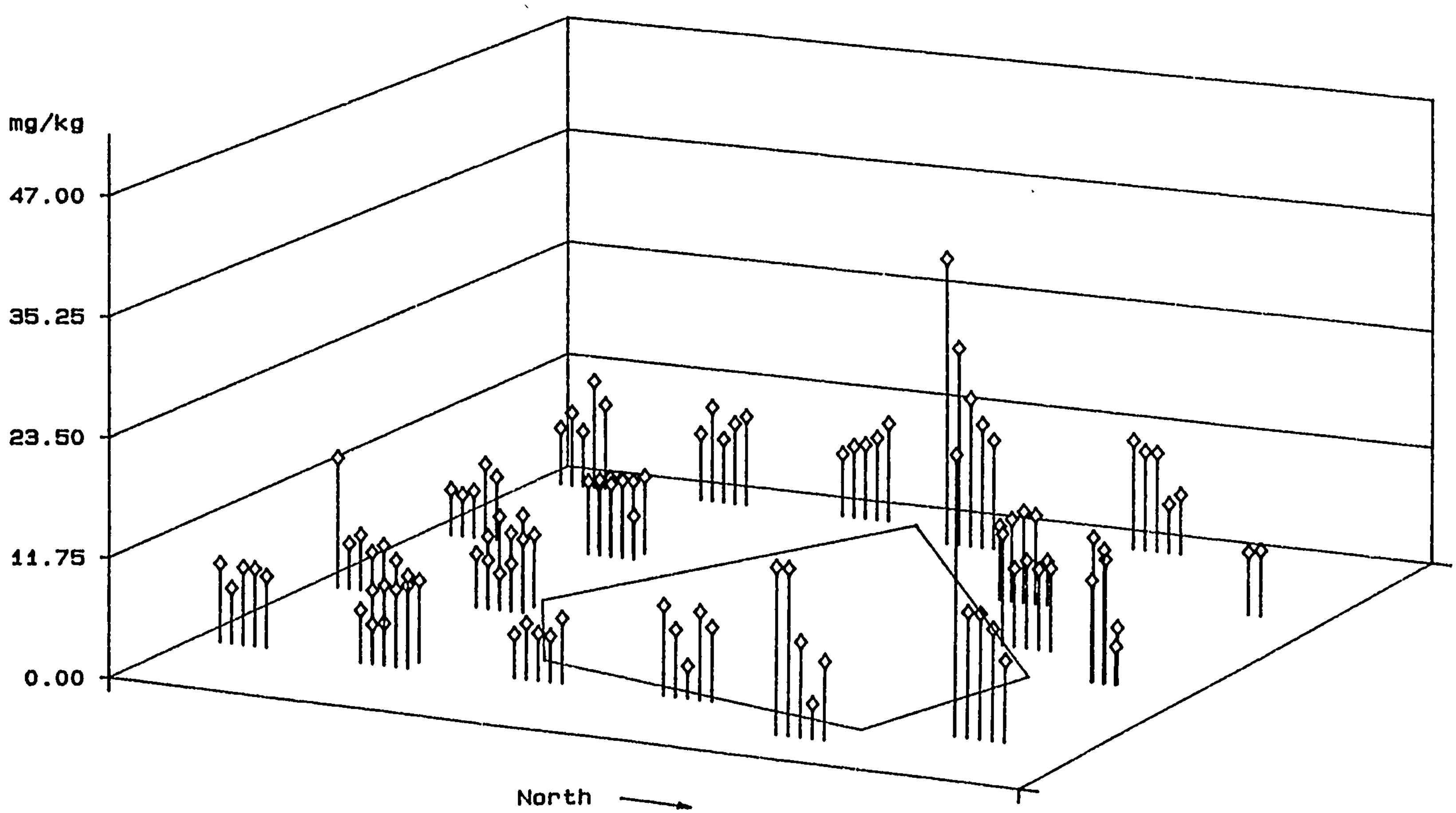
Cobalt at K–1070–A
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

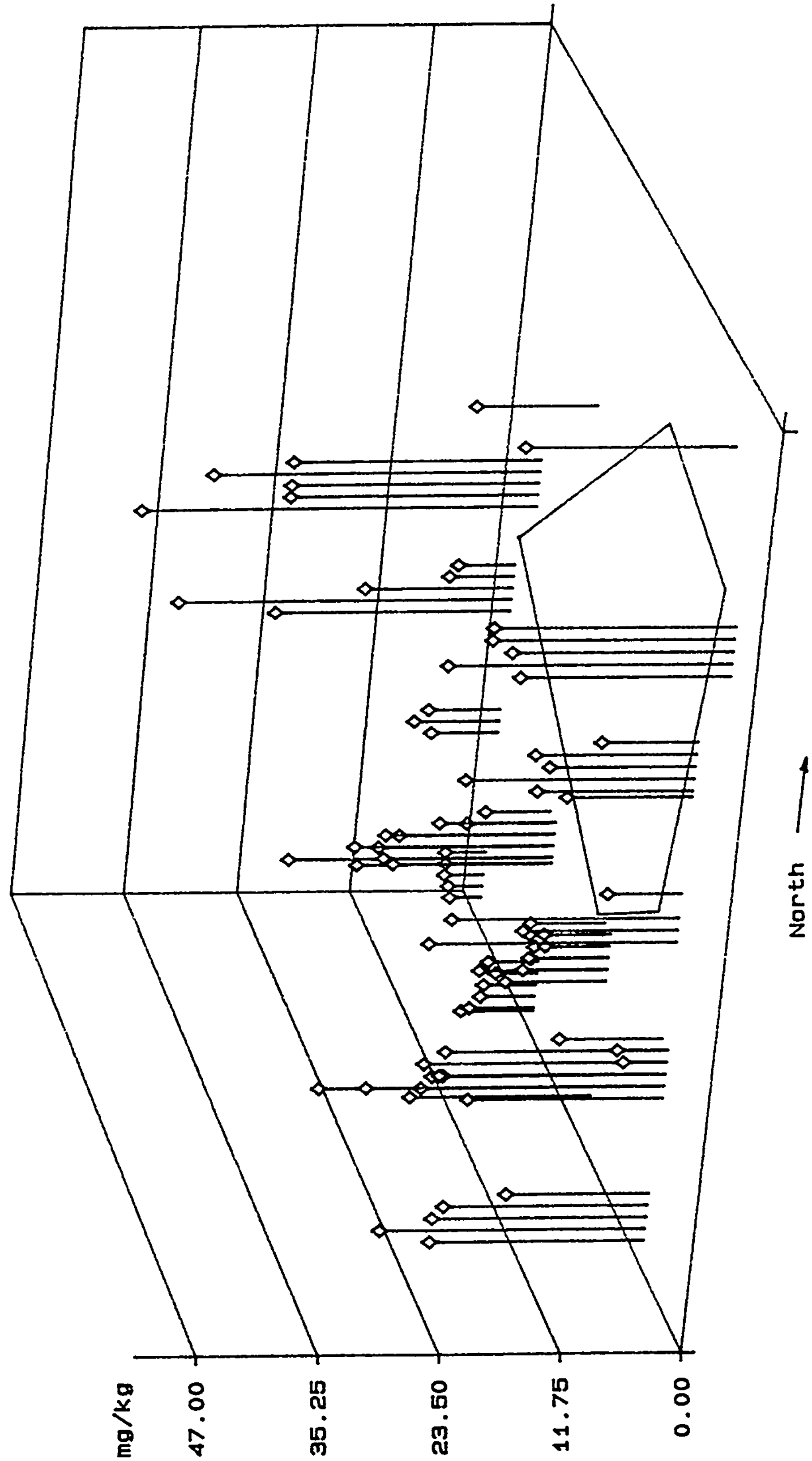
Nickel at K–1070–A

Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

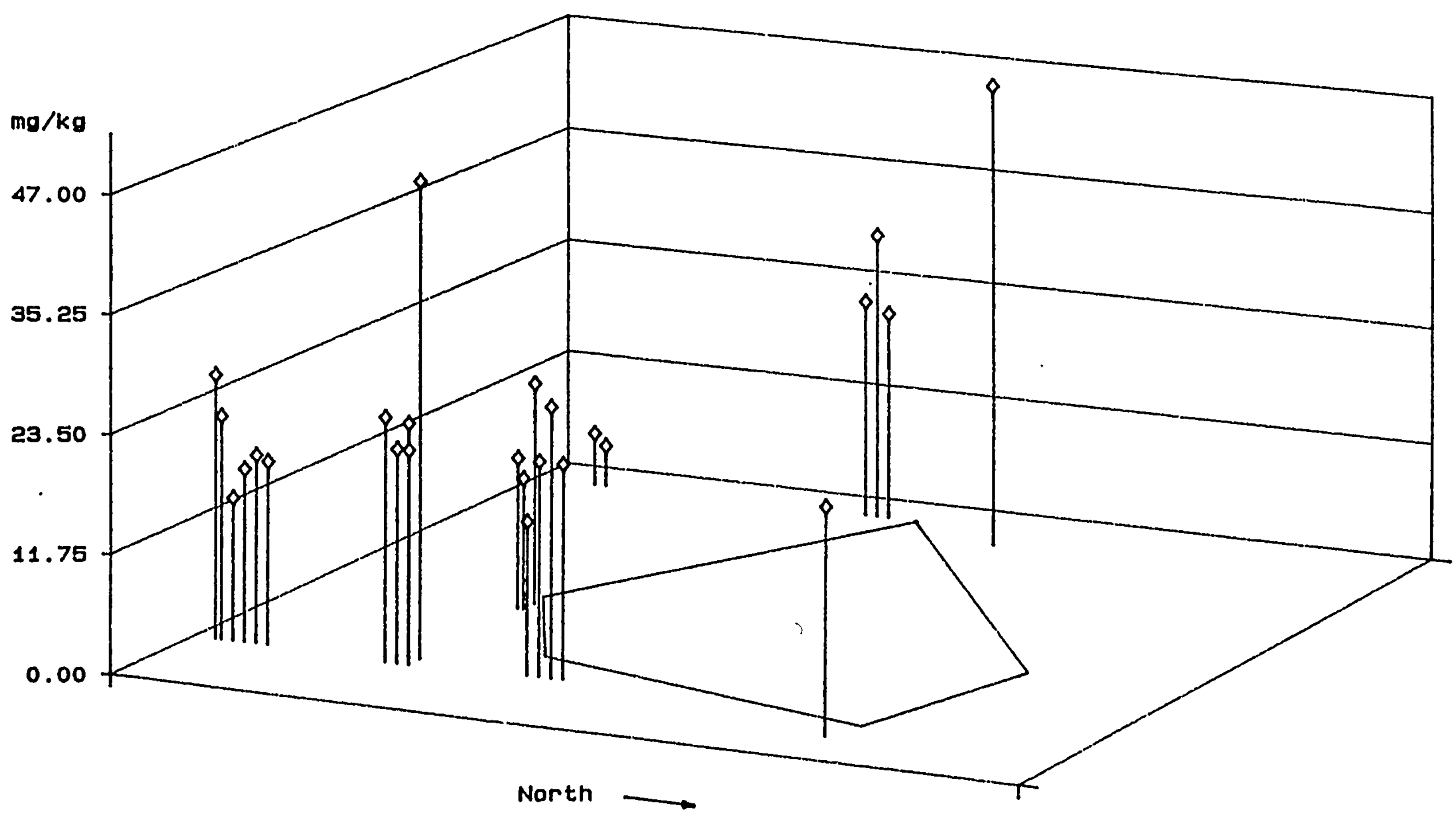
Nickel at K-1070-A
Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Nickel at K–1070–A

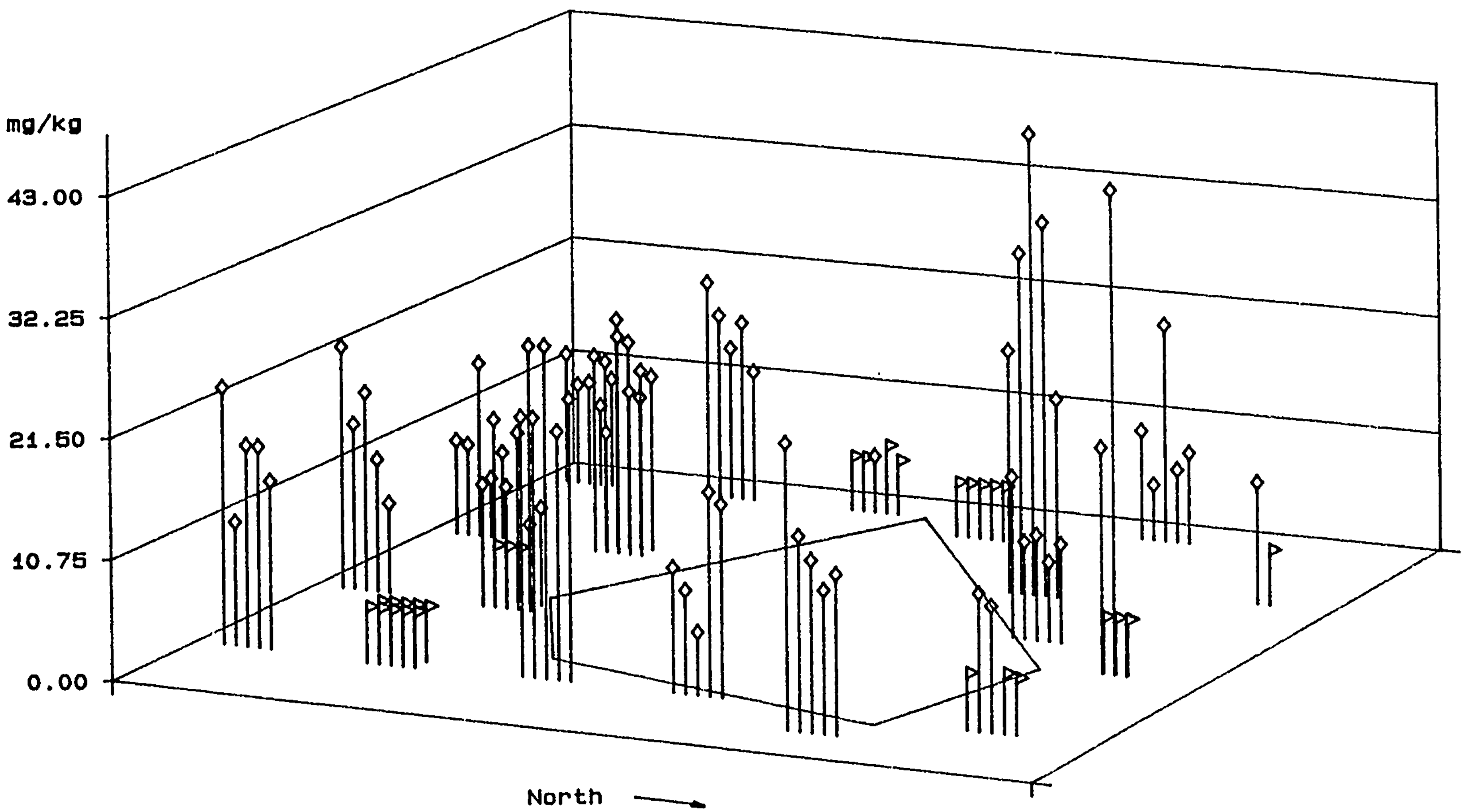
Depths= > 40 Ft.



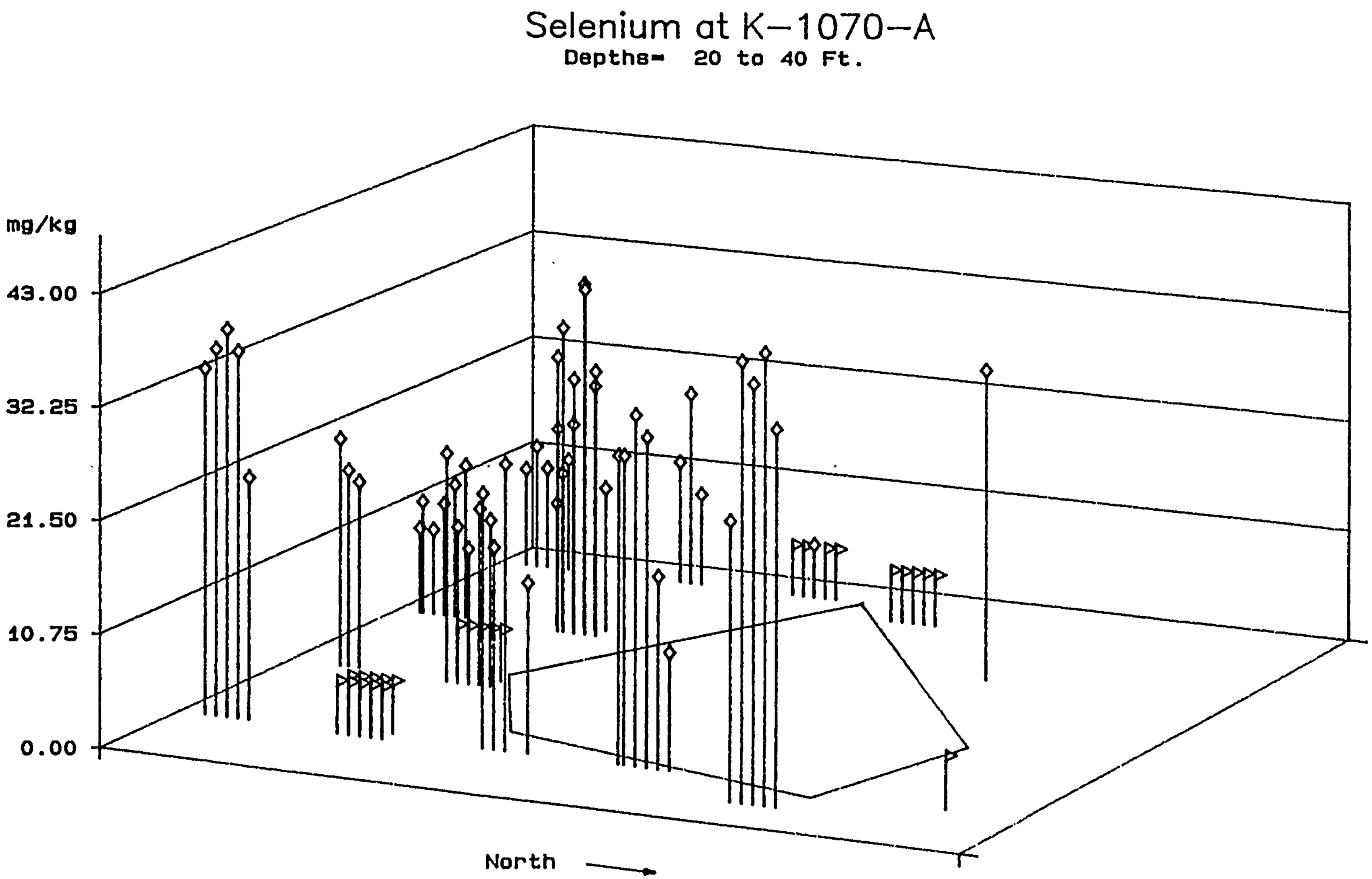
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Selenium at K−1070−A

Depths= 0 to 20 Ft.



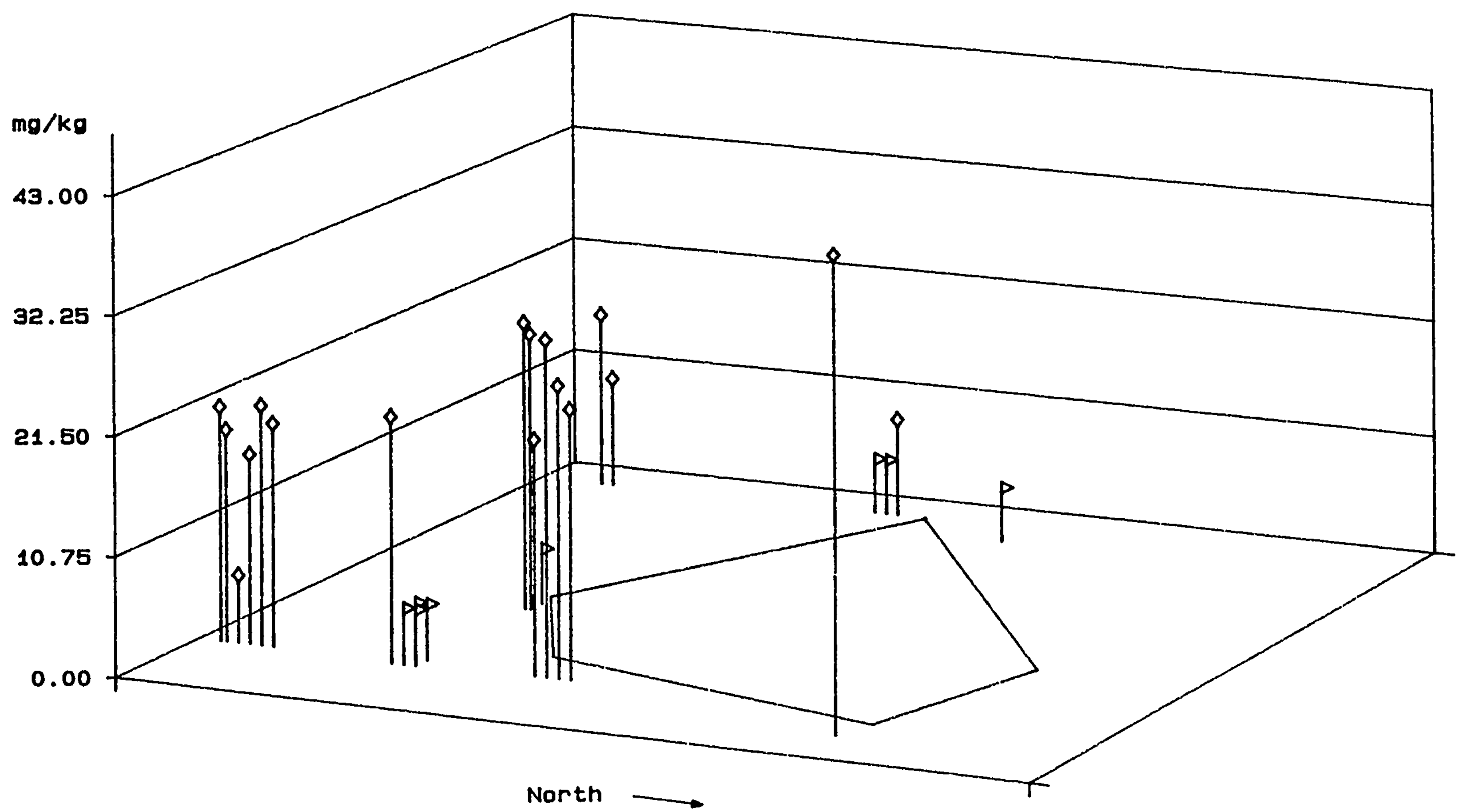
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data



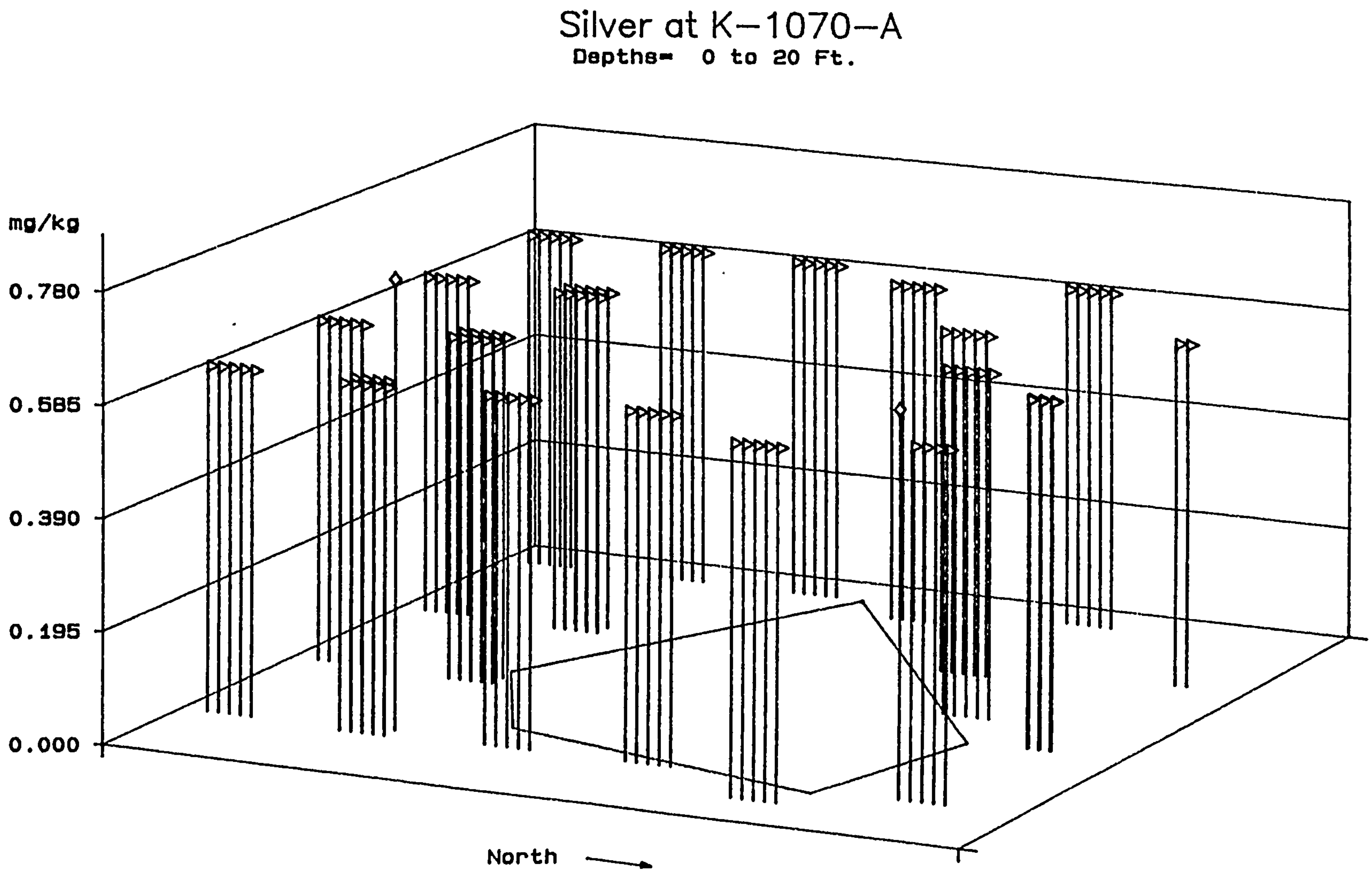
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Selenium at K–1070–A

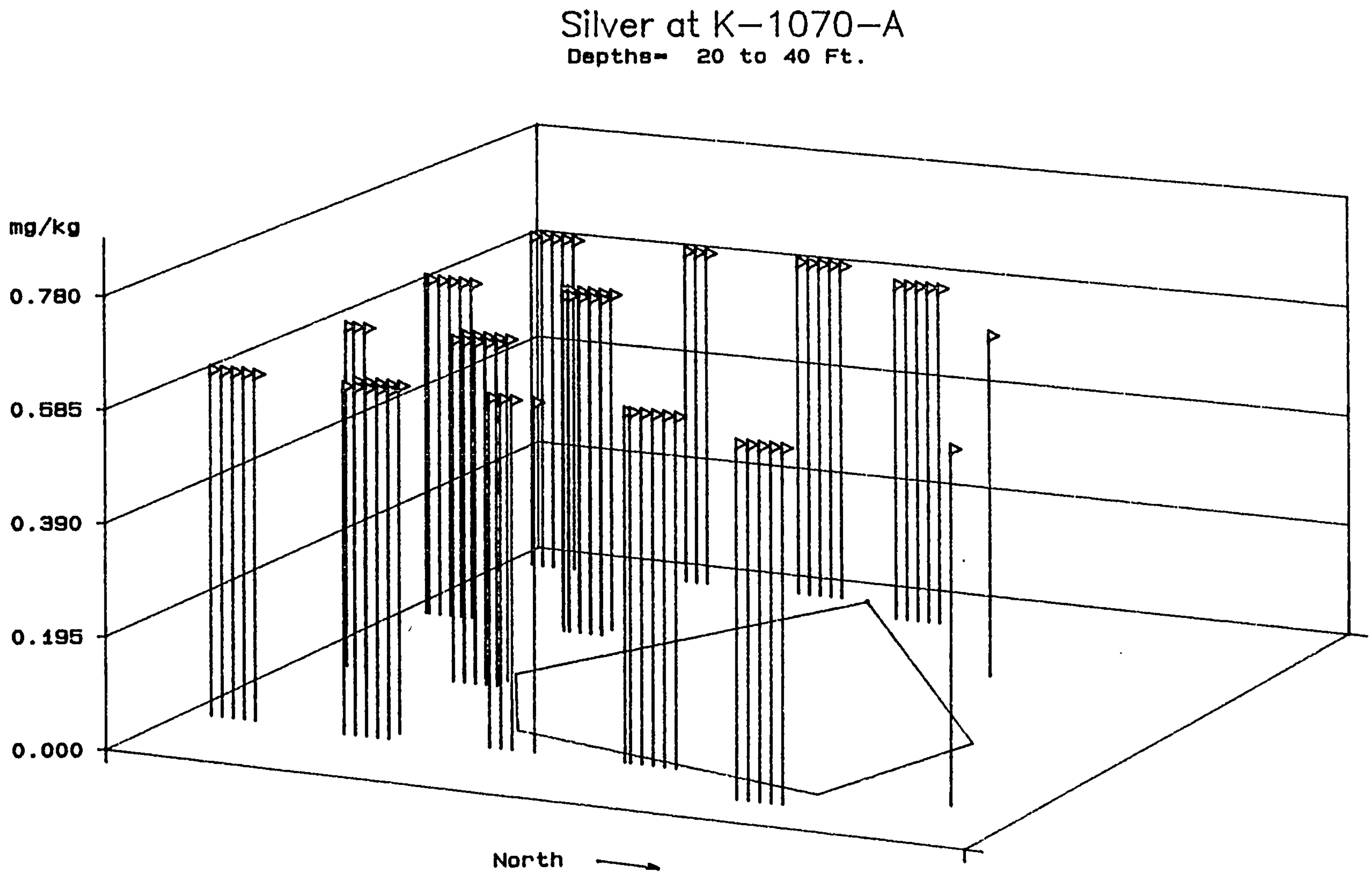
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data



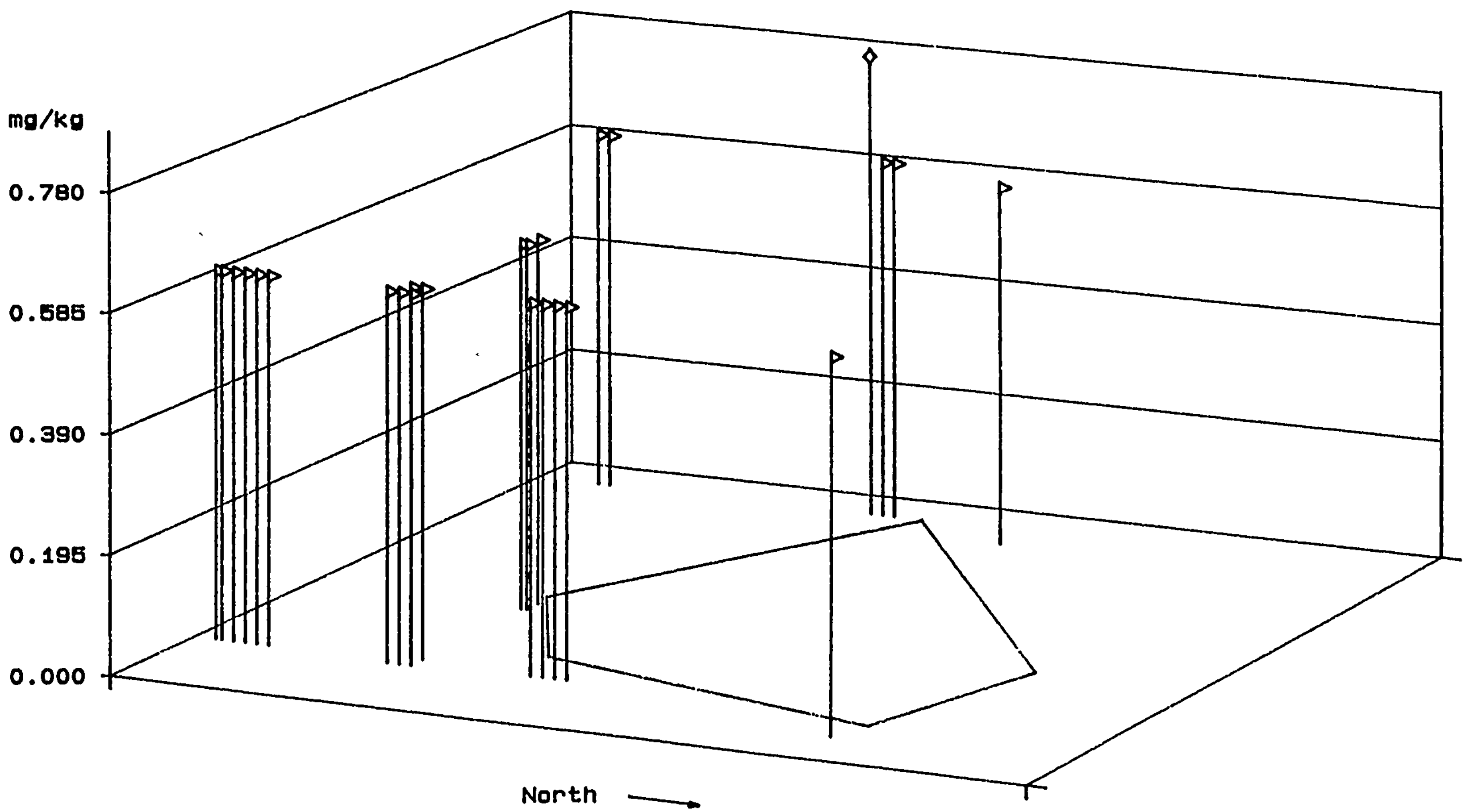
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

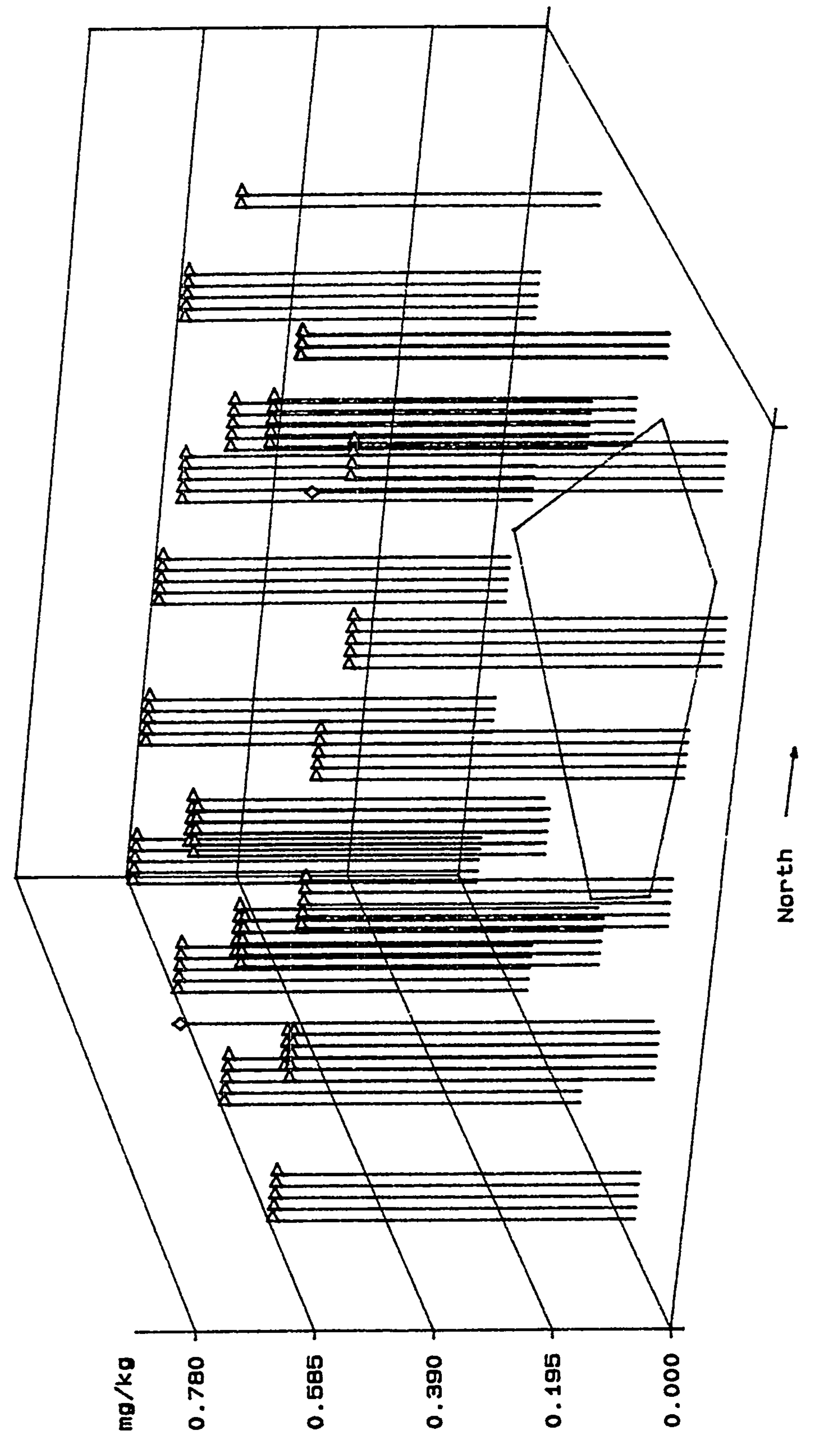
Silver at K–1070–A

Depths= > 40 Ft.



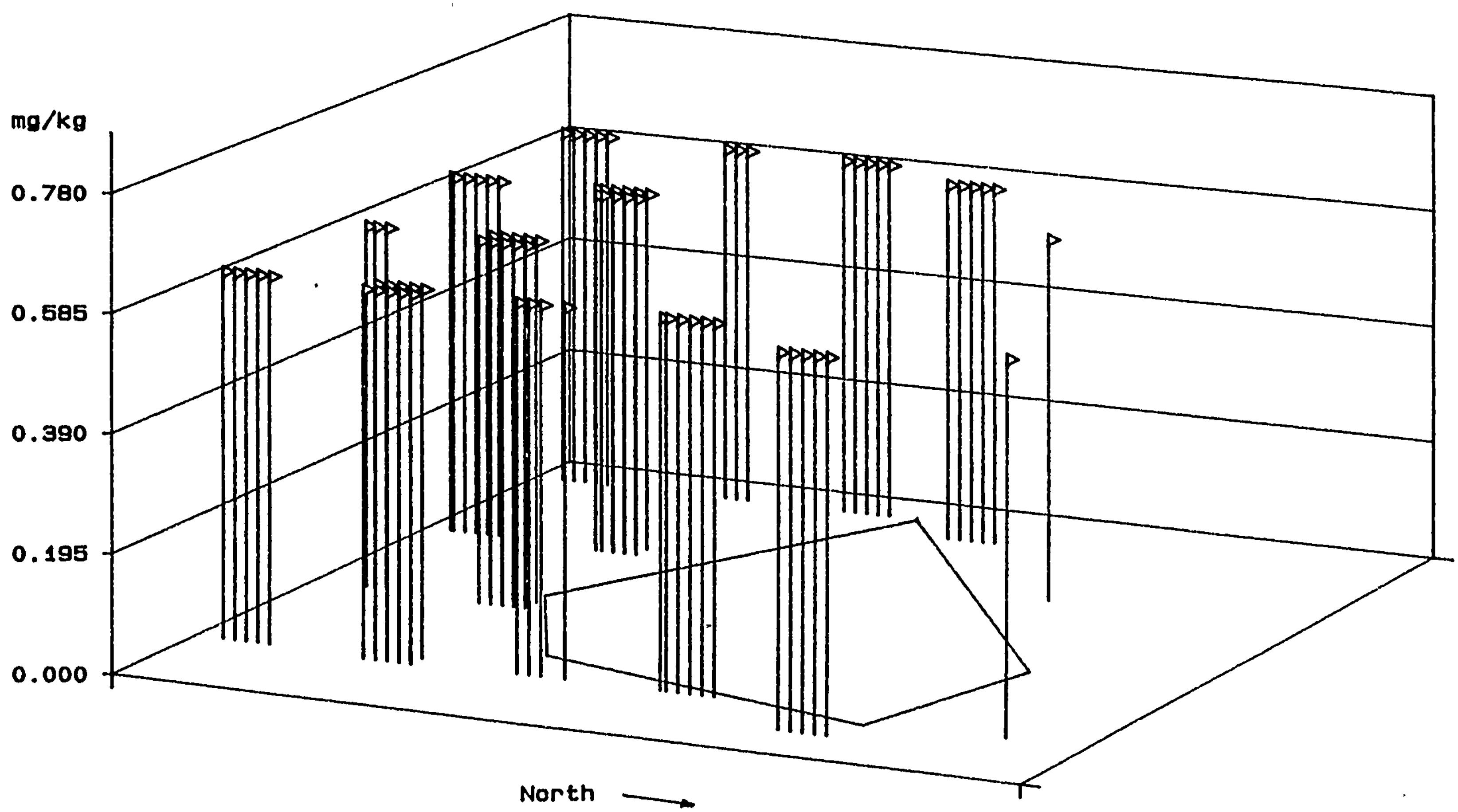
4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Uranium at K—1070—A
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

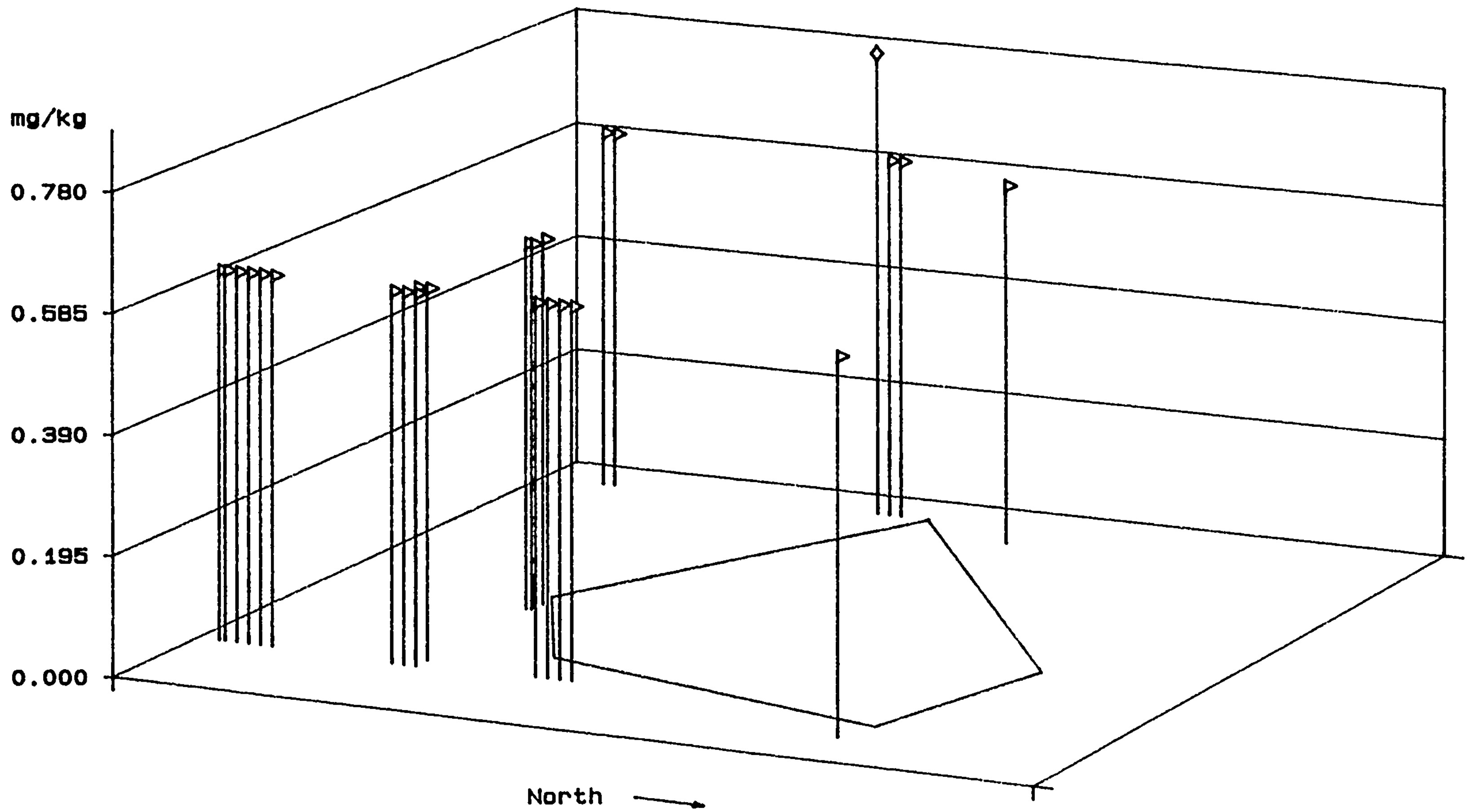
Uranium at K-1070-A
Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Uranium at K—1070—A

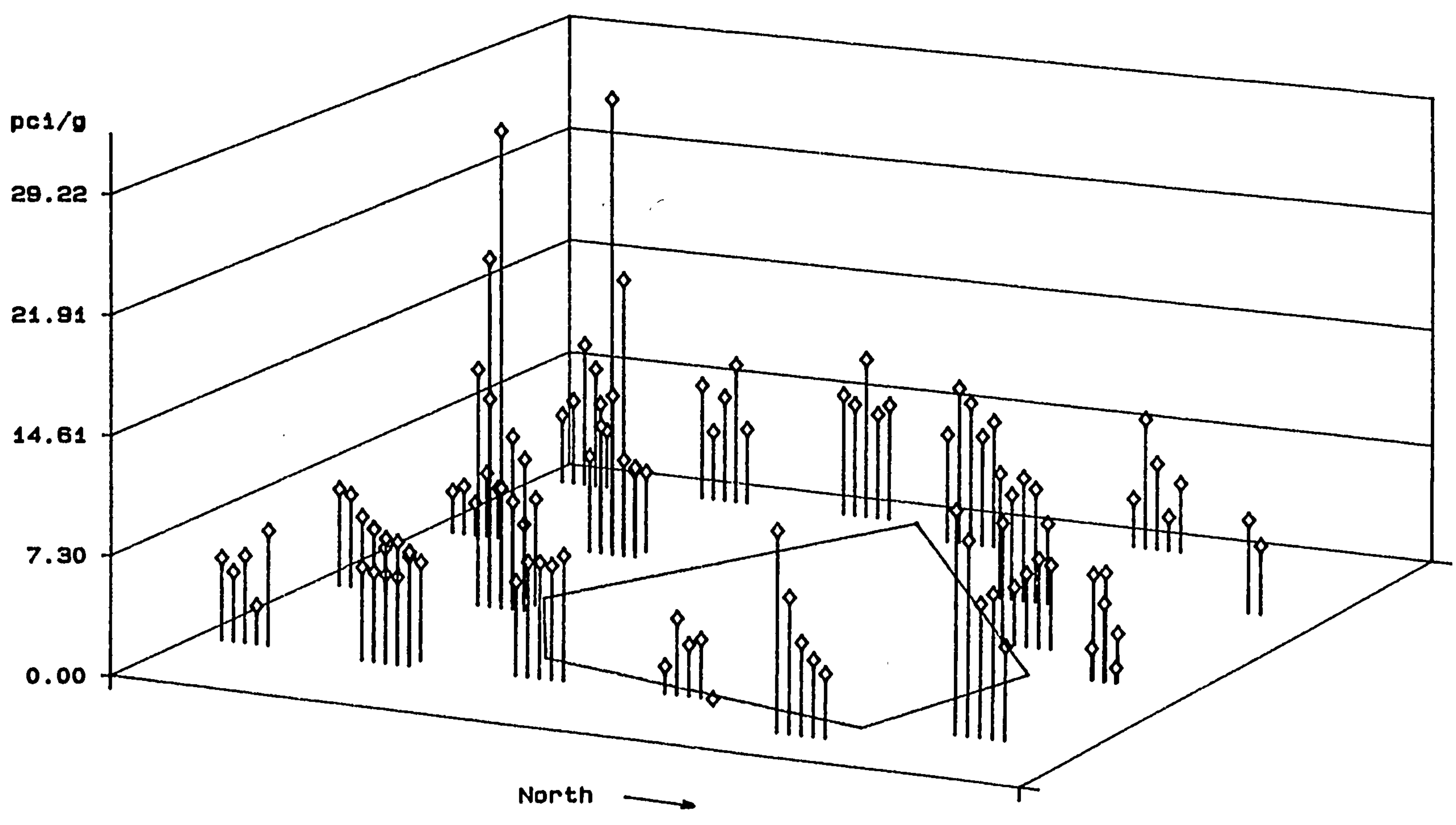
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Alpha Activity at K–1070–A

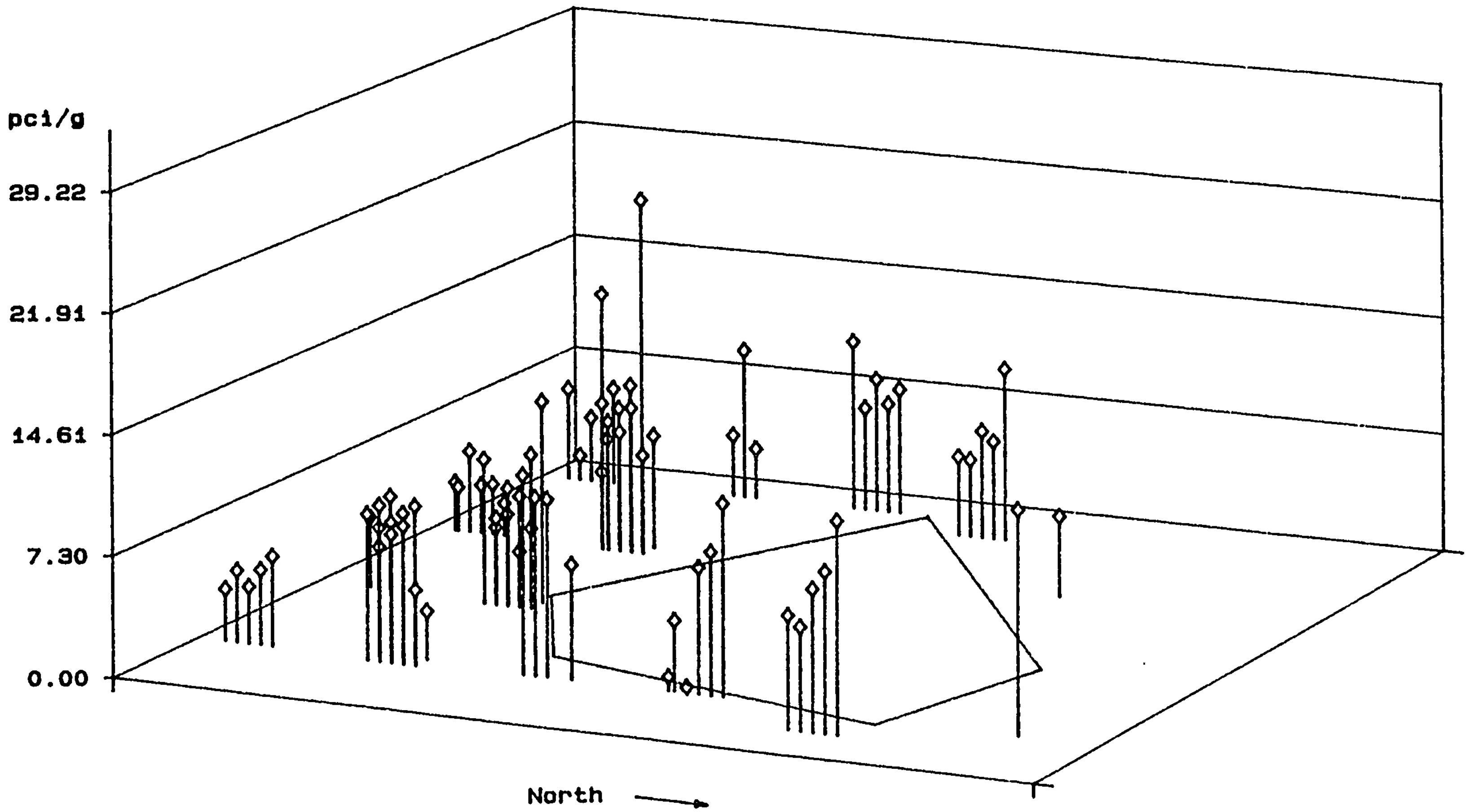
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Alpha Activity at K—1070—A

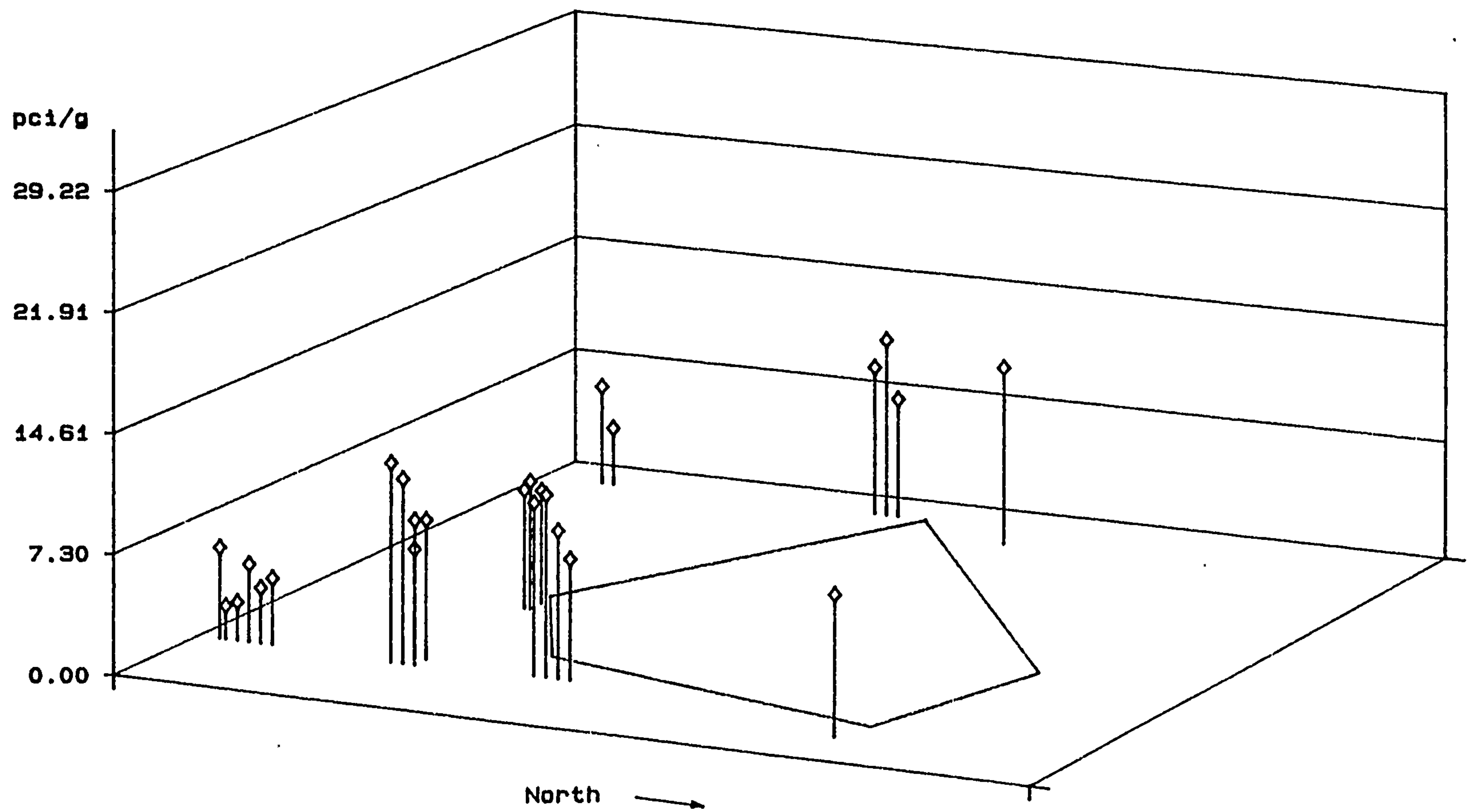
Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Alpha Activity at K-1070-A

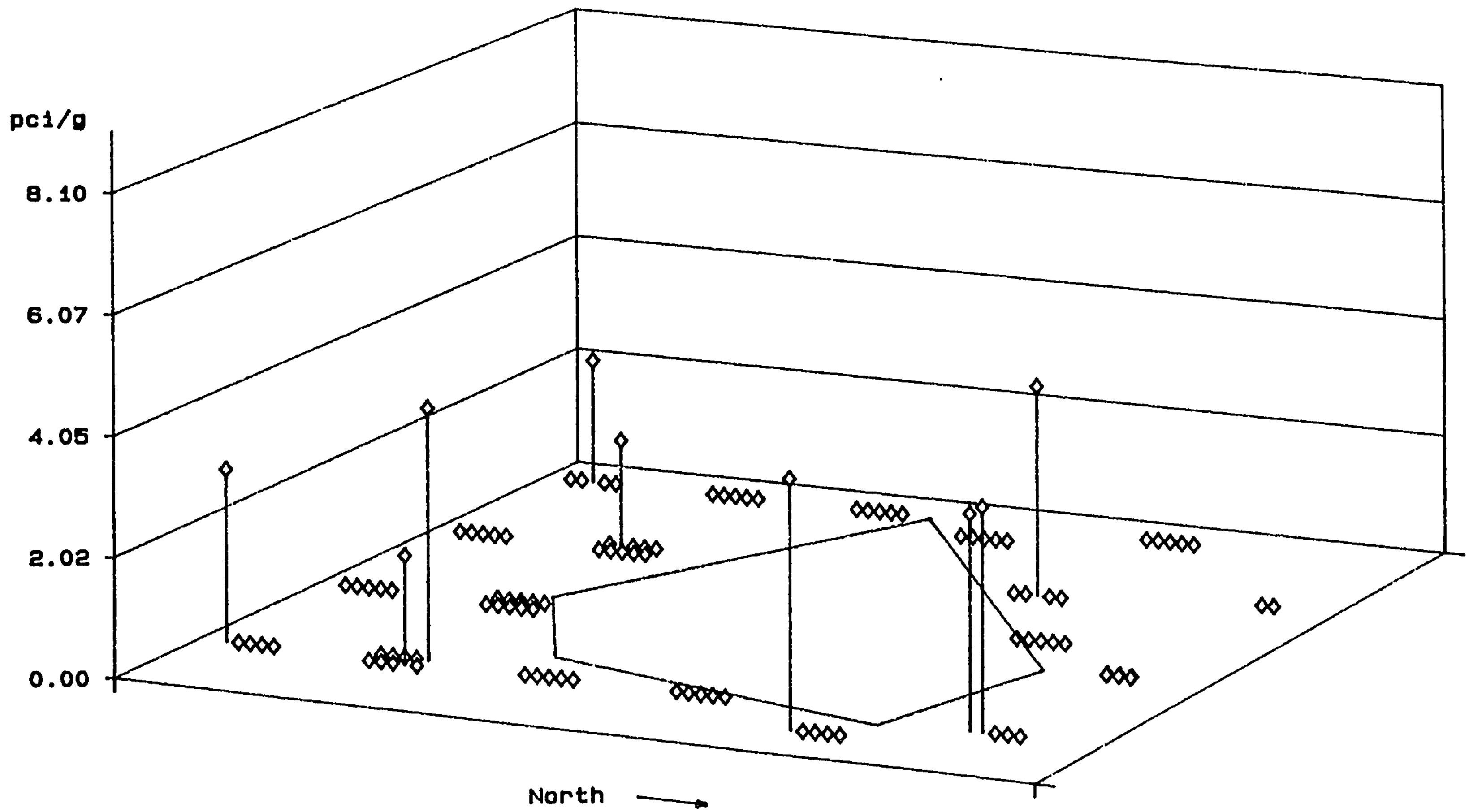
Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Gamma Activity at K—1070—A

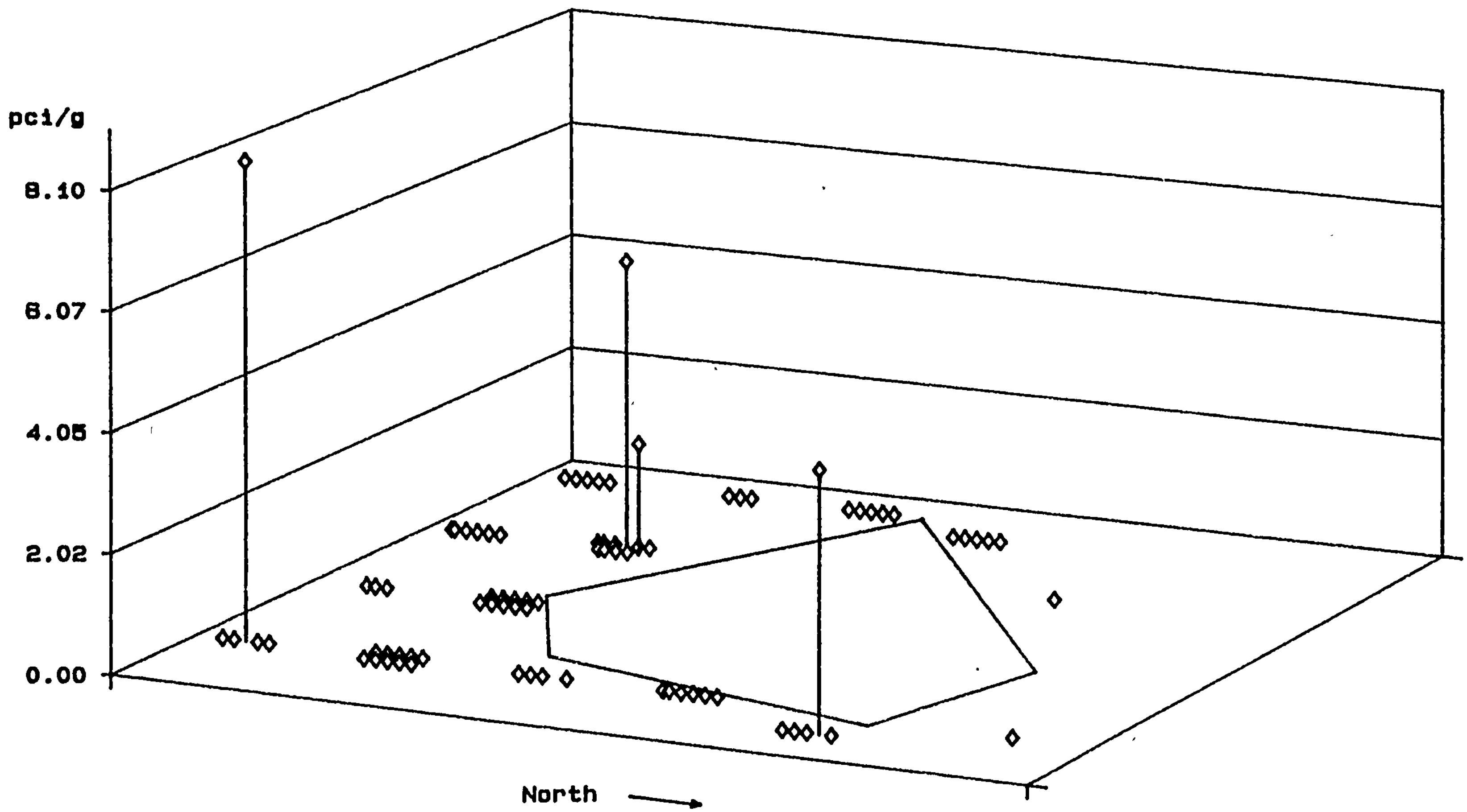
Depths= 0 to 20 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Gamma Activity at K—1070—A

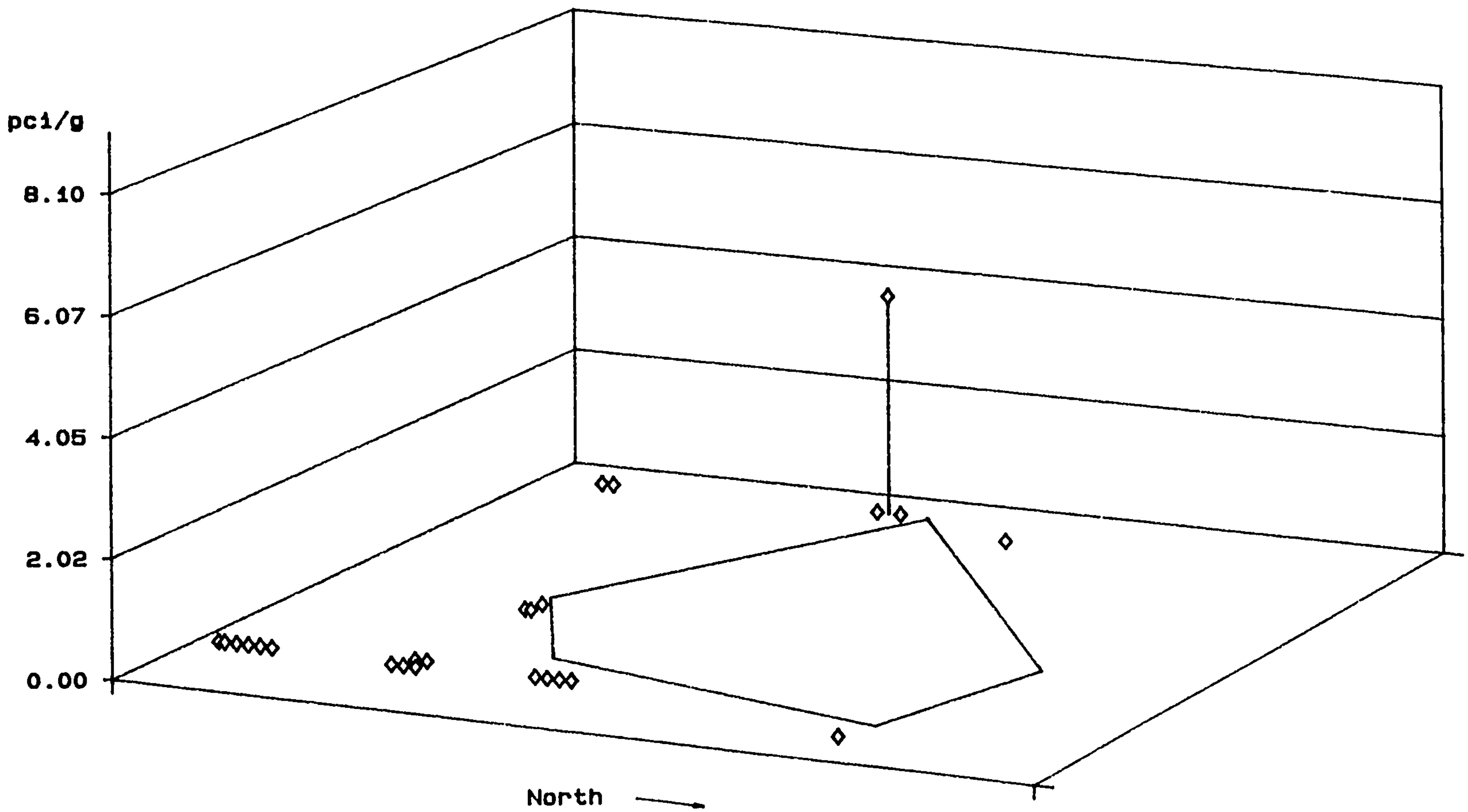
Depths= 20 to 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Gamma Activity at K—1070—A

Depths= > 40 Ft.



4 ft. Depths: Most Southerly are the Deepest
Flags represent Non-Detect data; Diamonds, the detected data

Appendix D

SUMMARY STATISTICS FOR THE K-1070-A BURIAL GROUND SITE VERSUS BACKGROUND COMPARISON

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA				
1,2,4-Trichlorobenzene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
1,2-Dichlorobenzene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
1,3-Dichlorobenzene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
1,4-Dichlorobenzene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
2,4,5-Trichlorophenol	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 4500	< 6158	µg/kg
2,4,6-Trichlorophenol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
2,4-Dichlorophenol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
2,4-Dimethylphenol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
2,4-Dinitrophenol	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 4500	< 6158	µg/kg
2,4-Dinitrotoluene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
2,6-Dinitrotoluene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
2-Chloronaphthalene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
2-Chlorophenol	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
2-Methylnaphthalene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
2-Methylphenol	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
2-Nitroaniline	Background	4	0	< 6200	< 4900	< 5500	μg/kg
	Site	18	0	< 7800	< 4500	< 6158	μg/kg
2-Nitrophenol	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
3,3'-Dichlorobenzidine	Background	4	0	< 2500	< 2000	< 2250	μg/kg
	Site	18	0	< 3100	< 1800	< 2481	μg/kg
3-Nitroaniline	Background	4	0	< 6200	< 4900	< 5500	μg/kg
	Site	18	0	< 7800	< 4500	< 6158	μg/kg
4,6-Dinitro-2-methylphenol	Background	4	0	< 6200	< 4900	< 5500	μg/kg
	Site	18	0	< 7800	< 910	< 5959	μg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
4-Bromophenyl-phenylether	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
4-Chloro-3-methylphenol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
4-Chloroaniline	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
4-Chlorophenyl-phenylether	Background		4	0 <	1300 <	1000 <	1138µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
4-Methylphenol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
4-Nitroaniline	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 910	< 5959	µg/kg
4-Nitrophenol	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 4500	< 6158	µg/kg
Acenaphthene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Acenaphthylene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Alkyl hydrocarbon	Background	3	3	JB 2520	JB 410	JB 1497	µg/kg
	Site	1111		JB 3030	JB 530	JB 1841	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
Anthracene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Benzo(a)anthracene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	1	J 200[a]	< 910[b]	<J 1192	µg/kg
Benzo(a)pyrene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	1	J 250[a]	< 910[b]	<J 1195	µg/kg
Benzo(b)fluoranthene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	1	J 240[a]	< 910[b]	<J 1194	µg/kg
Benzo(g,h,i)perylene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Benzo(k)fluoranthene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Benzoicacid	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 4500	< 6158	µg/kg
Benzylalcohol	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Butylbenzylphthalate	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	2	J 130[a]	<J 670[b]	<J 1107	µg/kg
Chrysene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
Di-n-butylphthalate	Background	4	2	830[a]	< 1100[b]	<JB 882.5	μg/kg
	Site	18	14	JB 940[a]	< 1000[b]	<JB 641.1	μg/kg
Diacetone alcohol	Background	4	4	JB 45300	JB 2000	JB 15800	μg/kg
	Site	16	16	JB 27000	JB 960	JB 6573	μg/kg
Dibenz(a,h)anthracene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
Dibenzofuran	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
Diethylphthalate	Background	4	4	B 4000	JB 550	JB 1763	μg/kg
	Site	18	17	B 9200	< 1000[b]	<JB 2723	μg/kg
Dimethylphthalate	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	1	JB 230[a]	< 910[b]	<JB 1211	μg/kg
Dioctyl adipate	Background	2	2	JB 2300	JB 2100	JB 2200	μg/kg
	Site	9	9	JB 8100	JB 1000	JB 3306	μg/kg
Fluoranthene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
Fluorene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg
Hexachlorobenzene	Background	4	0	< 1300	< 1000	< 1138	μg/kg
	Site	18	0	< 1600	< 910	< 1253	μg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
Hexachlorobutadiene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Hexachlorocyclopentadiene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Hexachloroethane	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Indeno(1,2,3-cd)pyrene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Isophorone	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
N-Nitroso-di-n-propylamine	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1256	µg/kg
N-Nitrosodiphenylamine	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Naphthalene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Nitrobenzene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
Pentachlorophenol	Background	4	0	< 6200	< 4900	< 5500	µg/kg
	Site	18	0	< 7800	< 4500	< 6158	µg/kg
Phenanthrene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
Phenol	Background	4	2	JB 52[a]	< 1150[b]	<JB 636	µg/kg
	Site	18	2	J 140[a]	< 910[b]	<J 1127	µg/kg
Phthalate ester	Background	3	3	J 1820	J 1100	J 1340	µg/kg
	Site	6	6	JB 15830	J 590	JB 6432	µg/kg
Pyrene	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	3	JB 780[a]	< 910[b]	<JB 1089	µg/kg
Unknown	Background	4	4	JB 11530	JB 3300	JB 6443	µg/kg
	Site	17	17	JB 14260	JB 630	JB 5976	µg/kg
Unknown hydrocarbon	Background	1	1	J 1220	J 1220	J 1220	µg/kg
	Site	5	5	JB 2960	JB 870	JB 1674	µg/kg
Unknown ketone	Background	1	1	JB 3500	JB 3500	JB 3500	µg/kg
	Site	1	1	JB 2300	JB 2300	JB 2300	µg/kg
Unknown siloxane	Background	1	1	JB 1130	JB 1130	JB 1130	µg/kg
	Site	4	4	J 6630	J 520	JB 2253	µg/kg
bis(2-Chloroethoxy)methane	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
bis(2-Chloroethyl)ether	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
bis(2-Chloroisopropyl)ether	Background	4	0	< 1300	< 1000	< 1138	µg/kg
	Site	18	0	< 1600	< 910	< 1253	µg/kg
bis(2-Ethylhexyl) sebacate	Background	1	1	JB 620	JB 620	JB 620	µg/kg
	Site	2	2	JB 3500	JB 710	JB 2105	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: BNA (continued)				
bis(2-Ethylhexyl)phthalate	Background	4	3	JB 1100	< 1000[b]	<JB 825	μg/kg
	Site	18	12	B 11000	< 1000[b]	<JB 2330	μg/kg
di-n-Octylphthalate	Background	4	2	JB 160[a]	< 1000[b]	<JB 582.2	μg/kg
	Site	18	13	JB 610[a]	< 1000[b]	<JB 456.4	μg/kg
			Analysis Type: ICP Metals				
Aluminum	Background	16	16	18000	7800	11659	mg/kg
	Site	162	162	24000	6200	12473	mg/kg
Antimony	Background	16	1	6.9	< 5	< 5.259	mg/kg
	Site	162	40	10	< 5	< 5.471	mg/kg
Arsenic	Background	16	5	27	< 5	< 10.12	mg/kg
	Site	162	66	69	< 5	< 12.16	mg/kg
Barium	Background	16	16	130	17	46.5	mg/kg
	Site	162	162	210	12	40.3	mg/kg
Beryllium	Background	16	16	1.2	0.25	0.538	mg/kg
	Site	162	162	2	0.135	0.57	mg/kg
Boron	Background	16	7	8.4	< 0.4	< 2.197	mg/kg
	Site	162	81	19	< 0.4	< 4.172	mg/kg
Cadmium	Background	16	3	0.51	< 0.3	< 0.325	mg/kg
	Site	162	86	2	< 0.3	< 0.59	mg/kg
Calcium	Background	16	16	1225	26	391.9	mg/kg
	Site	162	162	67000	17	1146	mg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: ICP Metals (continued)				
Chromium	Background	16	16	23	9.1	15.71	mg/kg
	Site	162	162	33	4.7	16.28	mg/kg
Cobalt	Background	16	16	130	2.5	19.29	mg/kg
	Site	162	162	210	1.7	19.9	mg/kg
Copper	Background	16	16	27.5	4.05	15.08	mg/kg
	Site	162	162	35.5	4.7	15.2	mg/kg
Iron	Background	16	16	43000	7700	24006	mg/kg
	Site	162	162	41000	13000	23455	mg/kg
Lead	Background	16	16	230	8.4	37.46	mg/kg
	Site	162	162	200	11	50.14	mg/kg
Magnesium	Background	16	16	1175	290	543.1	mg/kg
	Site	162	162	39000	260	873.2	mg/kg
Manganese	Background	16	16	3800	200	810.1	mg/kg
	Site	162	162	4600	84	1413	mg/kg
Molybdenum	Background	16	6	2.4	< 1	< 1.256	mg/kg
	Site	162	74	6.05	< 1	< 1.476	mg/kg
Nickel	Background	16	16	27	4.6	10.82	mg/kg
	Site	162	162	473.112.65 mg/kg			
Potassium	Background	16	16	1200	300	805.9	mg/kg
	Site	162	162	2100	99	768.8	mg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: ICP Metals (continued)				
Selenium	Background	16	8	20[a]	< 5	< 9.434	mg/kg
	Site	162	120	42	< 5	< 15.45	mg/kg
Silicon	Background	16	16	950	550	767.8	mg/kg
	Site	162	162	1000	330	787.6	mg/kg
Silver	Background	16	1	0.66	< 0.6	< 0.604	mg/kg
	Site	162	1	0.78	< 0.6	< 0.602	mg/kg
Sodium	Background	16	12	45	< 6.5[b]	< 20.01	mg/kg
	Site	162	99	91	< 2	< 14.32	mg/kg
Strontium	Background	16	16	6.4	0.87	2.715	mg/kg
	Site	162	162	5.95	0.71	2.238	mg/kg
Thorium	Background	16	0	< 20	< 20	< 20	mg/kg
	Site	162	0	< 20	< 20	< 20	mg/kg
Uranium	Background	16	0	< 3	< 3	< 3	mg/kg
	Site	162	26	82	< 3	< 5.832	mg/kg
Vanadium	Background	16	16	75	15	39.02	mg/kg
	Site	162	162	110	24	40.57	mg/kg
Zinc	Background	16	16	370	15	101.6	mg/kg
	Site	162	162	410	21	106.8	mg/kg
			Analysis Type: Mercury				
Mercury	Background	16	0	< 1	< 1	< 1	mg/kg
	Site	162	0	< 1	< 1	< 1	mg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: Other				
Extractable fluorides	Background	16	0	< 40	< 40	< 40	mg/kg
	Site	147	11	80	< 40	< 41.11	mg/kg
			Analysis Type: Radiation				
Alpha activity	Background	16	16	13.33	1.92	6.552	pCi/g
	Site	162	162	21.04	-0.95	6.574	pCi/g
Beta activity	Background	16	16	36.66	-4.59	14.76	pCi/g
	Site	162	162	319.4	-13	41.66	pCi/g
Gamma activity	Background	16	16	3.69	0	0.453	pCi/g
	Site	162	162	8.1	0	0.225	pCi/g
			Analysis Type: VOA				
1,1,1-Trichloroethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,1,2,2-Tetrachloroethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,1,2-Trichloroethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,1-Dichloroethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,1-Dichloroethene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
Analysis Type: VOA (continued)							
1,2-Dichloroethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,2-Dichloroethene(total)	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
1,2-Dichloropropane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
2-Butanone	Background	5	1	J 49[a]	< 29	<J 40	µg/kg
	Site	40	20	B 660	< 28	<JB 66.53	µg/kg
2-Hexanone	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
4-Methyl-2-pentanone	Background	5	1	J 6[a]	< 29[b]	<J 36.8	µg/kg
	Site	40	3	J 7[a]	<J 16[b]	<J 60.51	µg/kg
Acetone	Background	5	5	B 990	B 58	B 309.6	µg/kg
	Site	40	34	B 37000	< 35	<B 1489	µg/kg
Benzene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Bromodichloromethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Bromoform	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: VOA (continued)				
Bromomethane	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
Carbon disulfide	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Carbon tetrachloride	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	<J 11	<J 32.74	µg/kg
Chlorobenzene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Chloroethane	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
Chloroform	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	2	J 3[a]	<J 11.5[b]	<J 31.02	µg/kg
Chloromethane	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
Dibromochloromethane	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Ethylbenzene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Hydrocarbon	Background	4	4	JB 204	JB 14	JB 77	µg/kg
	Site	35	35	JB 619	JB 13	JB 97.96	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
Analysis Type: VOA (continued)							
Methylene chloride	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	1	J 5[a]	< 15[b]	<J 38.84	µg/kg
Styrene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Tetrachloroethene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Toluene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg
Trichloroethene	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	5	57[a]	< 14.5[b]	<J 34.9	µg/kg
Vinyl acetate	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
Vinyl chloride	Background	5	0	< 60	< 29	< 42	µg/kg
	Site	40	0	< 580	< 28	< 65.81	µg/kg
Xylene(total)	Background	5	0	< 30	< 15	< 21.2	µg/kg
	Site	40	0	< 290	< 14.5	< 32.89	µg/kg

Table D.1 Summary statistics for the K-1070-A burial ground site vs. background comparison (continued)

Analysis Name	Setting	Number of Results	Number > Detection	Maximum Result	Minimum Result	Average Result	Units
			Analysis Type: VOA (continued)				
cis-1,3-Dichloropropene	Background	5	0	< 30	< 15	< 21.2	μg/kg
	Site	40	0	< 290	< 14.5	< 32.89	μg/kg
trans-1,3-Dichloropropene	Background	5	0	< 30	< 15	< 21.2	μg/kg
	Site	40	0	< 290	< 14.5	< 32.89	μg/kg

[a]There is at least one result for this analysis which is less than the detection limit but is greater than the maximum real value.

[b]There is at least one result for this analysis which is above the detection limit but is less than the minimum of those results which are below the detection limit.

The reader is referred to the listing of the raw data for these results.

Appendix E

STATISTICAL ANALYSIS OF K-1070-A SOIL DATA

STATISTICAL ANALYSIS OF K-1070-A SOIL DATA

This statistical analysis of the K-1070-A soil data is a way of determining if the soil downgradient of the burial ground is different from the soil upgradient. In this context, *burial ground* refers to the graves, pits, trenches, and auger holes and the soil between them and in their immediate vicinity. This test was used to determine whether the overall mean concentration for a particular analyte of concern in the soil downgradient from the burial ground (consider the "site" data for this analysis) is less than or equal to the concentration upgradient (background) of the burial ground. The downgradient, or "site," area amounts to an irregularly shaped torus made up of the soil down to bedrock around the burial ground. Because no samples were taken from amongst the grave sites, it is impossible to make inferences concerning soil within this area from the sample results. The location of the upgradient soil samples is believed to be adequate for background. Those locations are in a wooded area uphill from the site. It is unlikely that the 4-ft soil cap over the site would have extended into this wooded area. As has been stated elsewhere in this report, the K-1070-A area is not downgradient of any other waste management unit.

The statistical test to be performed needs to determine whether the mean downgradient concentration in the soil for a particular analyte of concern is less than or equal to the mean upgradient concentration for the same analyte. The test is defined as follows:

Null Hypothesis: $\mu_{site} \leq \mu_{background}$
Alternative Hypothesis: $\mu_{site} > \mu_{background}$

where μ_{site} is the overall mean concentration for a particular analyte of concern in the soil downgradient of the grave sites, and $\mu_{background}$ is the overall mean concentration for a particular analyte of concern in the soil upgradient of the grave sites.

If direct calculations were at all possible, these means would be found by a three dimensional integration of the contaminant concentrations in the soil down to bedrock around the grave sites. Since the sample locations are from a regular grid around the grave sites and samples were taken at regular intervals to bedrock, each sample represents a similar shape and volume of soil. Thus, the averages of the results for the site area and background area can be used to estimate these means. Samples were taken every 4 ft to bedrock within the 100-ft × 100-ft grid, insuring good coverage of the area. An individual sample result then represents a 100-ft × 100-ft × 4-ft volume of soil.

Initially, the results from the 22 field replicate pairs (Table E.1) were averaged. Next, the results from the paired borehole locations were averaged at each sample depth. This yielded one result for each 100-ft × 100-ft sampling location at each sampling depth to bedrock. The site sample results were averaged together as well as the background results. These overall averages were compared with one another. Consider the difference between the average of the site sample results and the background sample results:

$$L = \bar{Y}_{site} - \bar{Y}_{background}$$

Table E.1 List of field replicate samples

Borehole Location	Depth (ft)
2	4
3	8
4	8
5	8
6	12
8	8
11A	24
11B	28
12	24
13B	8
14	20
17A	8
17A	44
17B	36
19	8
20	8
21	28
22	12
22	48
23A	8
23B	32
24	48

Based on the averaging described above and the definition for L, L can be viewed as alinear combination of the sample results, $L = \Sigma c_i Y_i$. The constants, c_i, are chosen in a manner that reflects the averaging of the field replicates and the paired boreholes and gives the correct weight to the site results and the background results.

To perform the proposed statistical test, the difference in the site and background averages is compared in light of the variability that is present in the data. This variability comes from three sources: small-scale spatial variability (the variability that would result from drilling many holes in a small area and analyzing sample results), sampling variability, and analytical variability. Because there were no laboratory duplicates taken or analyzed, it was not possible to separate the analytical variability from the sampling variability. The sum of these two sources of variability (sampling and analytical) can be estimated from the 22 field replicates. The estimate of the small-scale spatial variability essentially comes from the pairs of boreholes that were drilled at locations 11, 13, 17, and 23.

If $L = \Sigma c_i Y_i$, then $\mathrm{var}(L) = \Sigma c_i^2 \mathrm{var}(Y_i) = \mathrm{var}(Y) \Sigma c_i^2$, assuming that the individual sample results are independent and identically distributed. It is not clear whether this assumption holds entirely. A case could be made for correlation among samples within the same borehole, but for the purposes here that will be disregarded. The variance of a single result, var(Y), is the sum of the variances of the small-scale spatial component and the combined sampling and analytical component. The sampling plus analytical component of variance can be estimated from the sum of squares error of the 22 field replicated results. Estimating the small-scale spatial component of variance is not as straightforward. The small-scale spatial variance is estimated from both the sum of squares error found previously and the sum of squares that one gets from averaging the borehole pairs at each sample depth level. Then, the estimated variance of a sample result is

$$s^2(Y) = s^2(\text{small-scale spatial}) + s^2(\text{sampling and analytical})$$

A t-statistic can then be formed, $t^* = L / s(L)$, which has an approximate t-distribution with the number of degrees of freedom (df) associated with L that is estimated using a Satterthwaite approximation. The null hypothesis is rejected at the 0.05 level if $t^* > t_{0.05}(df)$.